University of Alicante

Faculty of Economy

Interuniversity Master in Development Cooperation

Speciality in Environmental sustainability

Mentor: Torregrosa Martí, Maria Teresa (University Institute of Water and Environmental Sciences)

Climate-friendly agriculture that feeds a region

Agriculture in times of climate change in the province of Alicante (Spain)

Master thesis

Jana Piske

Prolongación Avenida de Libertad 17c

03316 Benferri

piskejana@gmail.com

C935ZNM0R8D

Content

Table of Tables

Table of Figures

Abstract (English)

The chances and threats of agriculture on climate change are very ambiguous as it is one of the main anthropogenic activities contributing to climate change and can have a very negative impact on our environment. On the other hand, agriculture can conserve our landscapes, promote biodiversity and function as a carbon sink. This means agriculture is not in general good or bad in terms of climate change. Its judgment depends on the parameters used for its assessment. This thesis analyses the potential of ecological and intensive agricultural practices on the potential to mitigate and adapt climate change effects in the Alicante province in the period 1989-2019. The results are evaluated whether organic agriculture is a sustainable option to mitigate and adapt to the impacts of climate change in the province of Alicante. This investigation offers a more wholistic approach on the topic as it is not a merely quantitative research. The research question on the impact of climate change on the most common types of agricultural practices in the province of Alicante is assessed using quantitative methods first. But the discussion opens this narrow perspective to a broader understanding of sustainability. It is important to look at the different scales to evaluate the sustainability of agriculture. Organic agriculture offers the potential of sustainable and climate-friendly agriculture, but there are also areas that achieve good results with conventional agricultural practices. The strong trend regarding water-intensive fruits is alarming, as water scarcity already exists and can be expected to increase in the future. A struggle of resources is already foreseeable. The processes of soil erosion are also directly related to climate change and are strikingly high in olive cultivation, fruit trees, as well as grape cultivation. These are all important crops of the province and, in this context, of economic, environmental, and social importance. Special attention should be paid to the practice of soil recovery in fallow land. Because this study was also able to clearly show that fallow land poses a great risk to the soil and is not a sustainable practice in most cases. The bottom line is that climate change is a global challenge that must be reflected in local action. Agriculture has a very large share in anthropogenic climate change, but at the same time offers opportunities for adaptation and mitigation. The change from bad already naturalized agricultural practices to new or better ones always costs financial resources, education and persuasion. However, in the context of an economically, ecologically and socially sustainable agriculture, it is the only right way.

Keywords: Sustainable land management practices, organic agriculture, conventional agriculture, sustainability, soil erosion, geospatial analysis.

Abstract (Spanish)

Las posibilidades y amenazas de la agricultura sobre el cambio climático son muy ambiguas ya que es una de las principales actividades antropogénicas que contribuyen al cambio climático y puede tener un impacto muy negativo en nuestro medio ambiente. Por otro lado, la agricultura puede conservar nuestros paisajes, promover la biodiversidad y funcionar como sumidero de carbono. Esto significa que la agricultura no es en general buena o mala en términos de cambio climático. Su juicio depende de los parámetros utilizados para su evaluación. Esta tesis analiza el potencial de las prácticas agrícolas intensivas y ecológicas sobre el potencial de mitigación y adaptación de los efectos del cambio climático en la provincia de Alicante en el período 1989-2019. Los resultados se evalúan si la agricultura ecológica es una opción sostenible para mitigar y adaptarse a los impactos del cambio climático en la provincia de Alicante. Esta investigación ofrece un enfoque más holístico sobre el tema, ya que no es una investigación meramente cuantitativa. La pregunta de investigación sobre el impacto del cambio climático en los tipos de prácticas agrícolas más comunes en la provincia de Alicante se evalúa primero utilizando métodos cuantitativos. Pero la discusión abre esta perspectiva estrecha a una comprensión más amplia de la sostenibilidad. Es importante observar las diferentes escalas para evaluar la sostenibilidad de la agricultura. La agricultura orgánica ofrece el potencial de una agricultura sostenible y respetuosa con el clima, pero también hay áreas que logran buenos resultados con las prácticas agrícolas convencionales. La fuerte tendencia con respecto a las frutas con uso intensivo de agua es alarmante, ya que la escasez de agua ya existe y se puede esperar que aumente en el futuro. Ya es previsible una lucha de recursos. Los procesos de erosión del suelo también están directamente relacionados con el cambio climático y son sorprendentemente altos en el cultivo del olivo, los árboles frutales y el cultivo de la uva. Todos estos son cultivos importantes de la provincia y, en este contexto, de importancia económica, ambiental y social. Se debe prestar especial atención a la práctica de recuperación del suelo en tierras en barbecho. Porque este estudio también pudo mostrar claramente que la tierra en barbecho representa un gran riesgo para el suelo y no es una práctica sostenible en la mayoría de los casos. La conclusión es que el cambio climático es un desafío global que debe reflejarse en la acción local. La agricultura tiene una participación muy importante en el cambio climático antropogénico, pero al mismo tiempo ofrece oportunidades de adaptación y mitigación. El cambio de malas prácticas agrícolas ya naturalizadas a nuevas o mejores siempre cuesta recursos financieros, educación y persuasión. Sin embargo, en el contexto de una agricultura económica, ecológica y socialmente sostenible, es el único camino correcto.

Palabras claves: Prácticas de gestión sostenible de la tierra, agricultura orgánica, agricultura convencional, sostenibilidad, erosión del suelo, análisis geoespacial.

Acknowledgement

“When planning for a year, plant corn. When planning for a decade, plant trees. When planning for life, train and educate people.”
Chinese Proverb

In this work, the special importance of the correct scale and the chosen perspective became clear to me. Sustainable agriculture is a term that says something to everyone, but if you dig deeper, you can quickly identify differences in interpretation. At first it seems like a weakness of the term, but I also became aware of its strength during my master's thesis. Because sustainable agriculture is not characterized by the same measures and activities in the world, but by the same values and goals. The way there must look different.

Research also has a fixed goal, but the path changes when you run. I am particularly grateful for the people who prepared me for this path and offered me orientation in the right place. At this point I would like to thank the people who have accompanied me on my way.

A big thank you goes to Prof. Dr. Teresa Torregrosa, who accompanied me as a tutor. I am deeply grateful for your guidance, good comments, and the mediation of the right contact persons in case of doubts. Especially when it came to data research, you were a great motivator and support for me. In this context I would like to thank Prof. Dr. Jorge Olcina Cantos directly. He referred me to the important data sets that form the cornerstone of my research. His extensive knowledge in the works on climate and climate change in the region were also essential for this work.

Especially regarding the basic knowledge of the advantages and disadvantages of organic and conventional agriculture, I am grateful for the detailed explanations by Dr. Tiziano Gomiero.

At this point it is also the right moment to thank the University of Alicante, as well as Prof. Dr. Moises Hidalgo Moratal, Prof. Dr. Carlos Gomez Gil and Dr. Isra Morales Benito for the master’s program, which brought me into exchange with people from all over the world and shaped my view on the development cooperation.

And in the last place a special thank you for the moral and spiritual support: Roman Diaz, who tirelessly discussed the advantages and disadvantages, the history, and the future of agriculture in Alicante for hours and thus enriched this work in an indirect way. Barbara Piske, who taught me to be curious and to question everything critically.

I hope this work will do its part for a more climate-friendly agriculture.

Jana Piske

1. Introduction

Anthropogenic climate change is the greatest challenge facing humanity. It is not only through the annual climate summits and their resulting climate agreements that the issue has finally found its place in the political spotlight. The issue has also become the focus of public attention. Especially young people strike every Friday and demand the rescue of their future (https://fridaysforfuture.org/) and especially with the pandemic their movement became even more powerful with online demonstrations and the use of the hashtag #fighteverycrisis. Climate change is not a topic of climate activists or environmental scientists, the effects of climate change are real and measurable in many sectors of society (Crane-Droesch and Marshall 2019; Ecologistas en Acción 2019; Vargas-Amelin and Pindado 2014).

Economic, social, and environmental impacts are especially easy to identify around agriculture. Agriculture is an important topic in this context because nowhere else can the effects of climate change be experienced as closely as in agriculture. Extreme weather events, such as droughts, heavy rains, or floods, are increasing due to climate change and have a direct impact on agriculture (Masson-Delmotte et al. 2019, p. 9). This provokes short term shocks during extreme events which can destroy a complete harvest, but climate change has bigger impacts on local ecosystems. Global warming changes environmental patterns and forces the agricultural sector to adapt (Smith and Martino 2007).

Beside the threats of climate change our world faces the challenge of a rapidly increasing world population with expected 9.7 billion in 2050 (World population prospects 2019), while water scarcity in many regions will result in fewer yields (Crane-Droesch and Marshall 2019). Intensive agriculture provides a livelihood to many people working in the agriculture sector while meeting the challenge of feeding a growing population. But at the same time, intensive agriculture also threatens this very basis of life by destroying soils, releasing carbon dioxide, nitrogen, or other greenhouse gases (Masson-Delmotte et al. 2019).

The chances and threats of agriculture on climate change are very ambiguous as it is one of the main anthropogenic activities contributing to climate change and can have a very negative impact on our environment (Crane-Droesch and Marshall 2019). On the other hand, agriculture can conserve our landscapes, promote biodiversity and function as a carbon sink (Campbell et al. 2017). This means agriculture is not in general good or bad in terms of climate change. Its judgment depends on the parameters used for its assessment.

Previous research focused much on the opportunities organic agriculture offer to mitigate climate change. Various field experiments demonstrate the possibilities and show promising results that organic agriculture can protect the soil from erosion, prevent desertification and is

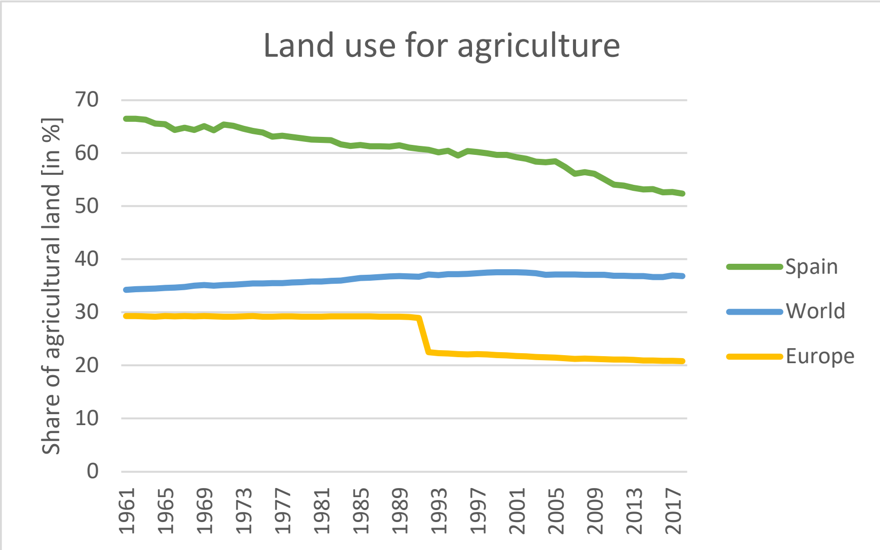


Figure 1 Share of agricultural land of the total land area in percentage and its development between 1961 and 2018. The share of agricultural land is in Spain higher than the global and European average (Source: Food and Agriculture Organization of the United Nations 2020, own elaboration)

in general more resilient to extreme weather events, as intensive agriculture (Khadra and Sagardoy 2019). But ways of mitigation and adaptation to climate change need to be assessed in their regional context, because what is feasible in one region may not be for another region (Smolik et al. 1995).

In order to assess different agricultural methods in terms of their potential to adapt to the effects of climate change, the country of Spain is very suitable, due to the special importance of its agriculture for Europe and the rather widespread and also professionalised practice of organic or ecological agriculture, as well as intensive agriculture. The land used for agriculture in Spain is with 52% (2018) of the total land very high and far above the European and global average (Figure 1). It is the second highest percentage of land devoted to agriculture in Europe just behind France (Worldbank 2020) and the leader of organic production in Europe (Infante Amate and González de Molina 2013). Agriculture is a huge part of the Spanish economy with contributing 2,8% of the GDP (2018) and in this year having the most hectares used for organic agriculture in Europe (Worldbank 2020).

But though Spain has a strong agricultural sector it has suffered from the extreme climate and the intense agricultural practices. For example, Alicante is a province with a great historic importance of agriculture while there is a water shortage (Moutahir 2016). In the past years the province of Alicante has experienced major land cover changes derived from urbanization at the coast, intensification of agriculture and the abandonment of agricultural activities in less productive soils (Bellot et al. 2007; Olcina 2017). At the same time the topography is very diverse which leads to a high diversity of microclimates in this province (Belda and Meliá 2000; Olcina Cantos and Moltó Mantero D.L. 2019).

Moreover, the Mediterranean region has always been plagued by intense water scarcity, desertification processes and soil erosion (Moutahir 2016). These are problems that can be found in many regions of the world and are likely to intensify because of climate change (Masson-Delmotte et al. 2019). This makes this research particularly important, as we can investigate which methods of agriculture are particularly promising in a context of water scarcity and high soil erosion. Especially in the context of agriculture it is important to keep in mind that agricultural practices should always be chosen on basis of the regional characteristics and needs. Some sustainable practices can be harmful in other regions (Gomiero et al. 2011; Masson-Delmotte et al. 2019). Producers with a long history of intensive or organic farming methods can be found and as well agricultural sites in the process of transformation. This allows us to assess possible development strategies for agriculture in countries with similar environmental conditions.

A challenge for the research will be the very poor database on farming practice and the categorisation of organic or intensive. Very little data is available for small areas or in small scales. The special problems regarding this research are further explained in the section 3. The categorisation and data preparation should be developed as part of this master thesis.

A broad challenge is to explore the link between climatic influences and agricultural practice. Climate always shows some variability, and it is difficult to draw a precise line between this and normal climate variability and climate change. The normal climatological period of 30 years is almost respected in our study period from 1990 to 2019, but longer time periods need to be investigated for the study of climate change impacts (Gomiero et al. 2011). However, it is certain that extreme weather events will increase and there are climate simulations for the region that can predict the effects of climate change with a high degree of probability (Masson-Delmotte et al. 2019).

Therefore, this thesis analyses the potential of ecological and intensive agricultural practices on the potential to mitigate and adapt climate change effects in the Alicante province in the period 1989-2019. One research question shall be tried to answer in this thesis: Firstly, regarding the research available I want to investigate the impact of climate change on the most common types of agricultural practices in the province of Alicante. Secondly, I want to discuss the results if organic agriculture is a sustainable option to mitigate and adapt to the impacts of climate change in the province of Alicante.

To answer the research question a deeper look has to be taken on the development of environmental parameters in relation to climatic parameters. To evaluate the climatic impact on the environment and not weather changes a time frame must be long enough; 30 years is defined as a normal climatic period (Hulme et al. 2009). A special attention will be given on extreme weather events as those are the biggest threat to the agriculture. To estimate the damage or no-damage resulted from the extreme weather events different parameters with agricultural relevance will be used. This must be done for a long timeframe as results of changes in agricultural practices will be shown with delay. An assessment using geospatial data would be desirable but because of a lack of data this can only be done for a very limited set of figures. This assessment of the relation of climatic and agricultural parameters will help to understand in what way the field experiments on mitigation and adaptation strategies of climate change in the sector of agriculture can be transferred to real life data. As a regional analysis has not yet been done it will be an important result to identify the real opportunities of those strategies in the everyday life.

To discuss the findings of the research question the assessment of the agricultural strategies will be amplified with a wider perspective. After assessing the agricultural practices from an only environmental perspective the discussion has the objective to include social and economic perspectives into the assessment. Agriculture is of course a main driver of climate change and plays an important role in the mitigation and adaptation of climate change (Masson-Delmotte et al. 2019). But solution approaches need support in the society to accept the changes and must be economical to be a sustainable strategy for a country. With further parameters these aspects will be included in the analysis to have a more complete assessment of the possibilities and limits of organic agriculture as strategy to mitigate and adapt to climate change.

In this line this thesis has the objectives to analyse the evolution of agricultural and climatic indicators in the period 1989-2019, identify the chances and challenges of conventional and organic agriculture in adapting to climate change and to assess their limits and possibilities as sustainable strategy to adapt and mitigate climate change in the province of Alicante.

This thesis contains six chapters. Their contents and their role for this thesis are explained in the following section.

To analyse the chances of organic agriculture to combat the effects of climate change it is important to make this analysis holistic and close to the reality of the region. As a range of more theoretical approaches have been developed already to evaluate the chances this thesis aims to put those results in a regional context. To do so it is important to analyse the regional necessities of the province Alicante as an agricultural producer. This will be done in the first chapter giving the theoretical knowledge of Alicante as a producer, organic agriculture as a strategy to adapt to climate change and sustainability in the context of agriculture. In this chapter the main points of critique as well as the expected outcomes as results from previous research will be compiled to be put in relation to the subsequent research. The third chapter introduces the data sets and the method used to answer the research question will be described. The fourth chapter focuses on presenting the results of the applied method structured into sections. The fifth chapter answers the research question while discussing the results. The discussion will be based on the main points identified in the second chapter of this thesis. This shows the regional limits of the transferability of general research to certain regions like the province of Alicante. Limits of this thesis and further investigation needed are described to address the outcomes and secondary open research questions derived from this research will be presented. All explanations are summarized, the results situated in the general context of sustainability and a brief outlook is given in the final chapter six.

2. Theoretical Framework

To understand better the investigation in the following chapter the development of the agriculture in the study area and its weather conditions influencing it will be described. In the second section the different agricultural practices of the region will be described and related to former investigation results assessing different agricultural practices and their potential to adapt and, in some cases, even mitigate climate change. At the end to answer the second research question in what way the organic agriculture can be a sustainable solution to mitigate climate change in the region, the different aspects, and theories of assessing sustainability will be presented in the third section. This background information will help to understand and assess better the results of the investigation in chapter 4 and will form the basis to discuss the results of this thesis.

2.1 Focus 1: Alicante as an agricultural producer

The province of Alicante is part of the Valencia community in the southeast of the peninsula of Spain. It is the most southern of the three provinces of the community and covers 5,816.5 km^2 (INE 2021). The province named after the province capital city is home to 4% of the Spanish population and prominent for foreigners to choose as a second residence or retirement home (INE 2021).

<u>Agriculture and its role for the economy</u>

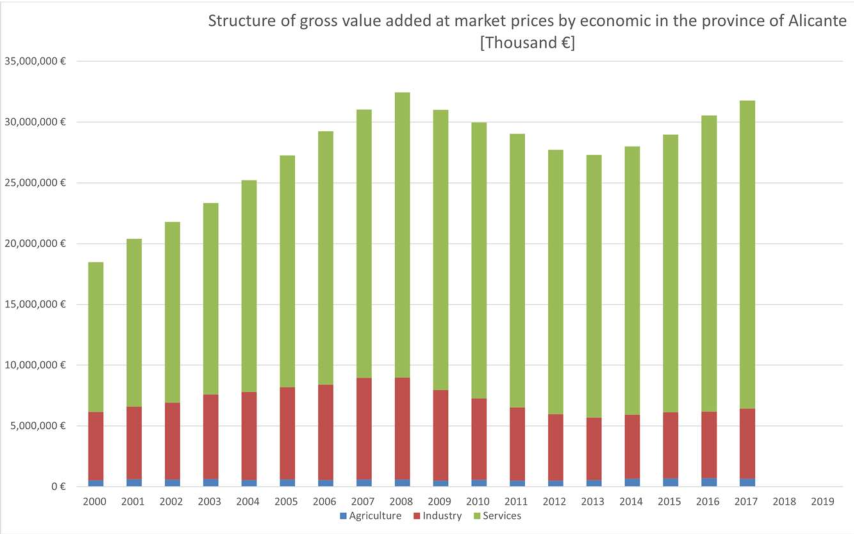


Figure 2 Distribution of gross value added at market prices by economy sector in the province of Alicante over the period 2000-2017. (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

The economy is dominated from the service sector, but in general agriculture plays a big role in the economy of the province. The gross value added has increased until its breakdown in 2008 caused by the financial crisis, which hit Spain especially hard (Neal and García-Iglesias 2013). But as shown in Figure 2 the gross value added of the service and industry sector were affected by the crisis, while agriculture took very limited damage. The agriculture serves to cover the needs of the own population, but a big share of the products are exported to countries in the EU (Food and Agriculture Organization of the United Nations 2020). In the sector of agriculture, a slight increase of gross value added can be observed.

Agriculture has a very high land use rate compared to other economies and therefore 173 320 hectare (30%) of the surface of the province are used for agriculture Conselleria de Agricultura,

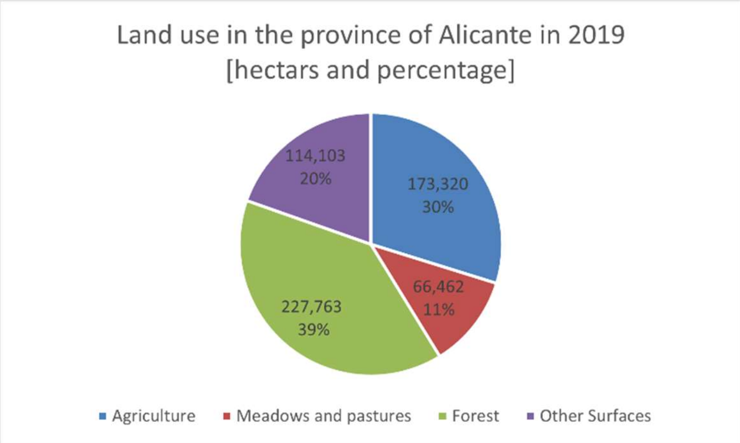


Figure 3 The main land use is forest with 39% and the second highest is Agriculture with 30% in the province of Alicante in the year 2019. (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019. This is 18% less than in 1997 when 48% of the Surface was used for agriculture. In 2019 agricultural land use is the second biggest land use category right after forest (see Figure 3). While the surface used for agriculture has declined, the modernization of agriculture helped to keep the production volume stable (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). This means less hectares of land are used for the same amount of harvest and with the improvement of farming practices the quality and therefore the economic value of the products has increased.

The diversity of crops plants in the province has declined over time. A wide range of Cereals, tubercules, vegetables, and other crops in general have been cultivated in the 90s. In 2018 it is easy to identify the main crops **citrus fruits** and **vegetables** in Figure 4. According to the land use classified by crops the main crops are **citrus fruits, other fruit trees, olives, grapes** and **vegetables** (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019).

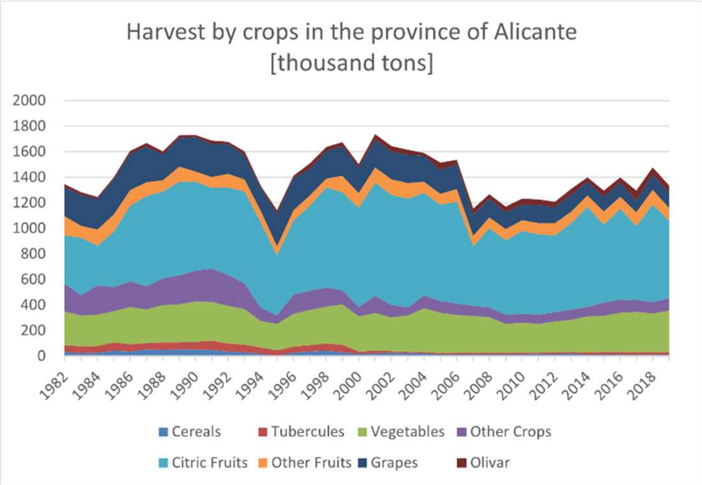


Figure 4 The main crops according to harvest volume are citric fruits and vegetables. (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

Climate and climate change in the province

The province of Alicante is located between XUTM 730400-760400 and YUTM 4272000-4304000 (Instituto Geográfico Nacional 2021) and has a wide topographic complexity influencing the climate. As Olcina Cantos and Moltó Mantero (2019) describe it in their book "Climas y tiempo del pais Valenciano" it is not possible to speak of a single climate in the province rather of various climates uniting the high dryness with extreme levels of precipitation in a rather small area. In the province are 3 different climate categories all in the class B after Köppen. The class B describes a dry climate which is mainly the semi-arid steppe climate and in one area the hot desert climate (Aemet 2018). The climate is influenced by mountains in the northern part and a mix of steppe and flat wetlands in the south. It is along the Mediterranean Sea which has a high influence on the climate as well (Belda and Meliá 2000). Because of the very dry climate it has only few rivers but rather ramblas (dry riverbeds) which fill up during heavy rainfalls. In this region especially water scarcity, desertification, and erosion due to heavy climate events are the main challenges for a sustainable agriculture.

The diverse climate allows a wide range of agricultural activity, but water scarcity is often a problem and intense irrigation especially for not regional plants is essential. The problem of water scarcity, soil erosion and processes of desertification will increase in the future according to the prospects of climate change (Masson-Delmotte et al. 2019).

In the Mediterranean a notable increase of the average temperatures occurred during the last decades especially in the Iberian Peninsula (Moutahir 2016). The **temperature** has increased in general over the whole peninsula of Spain of around 0,3° Celsius per decade (Ecologistas en Acción 2019) and will increase in the province of Alicante between 2-4°C in the next two decades (see Figure 5). Various studies (Moutahir 2016; Ecologistas en Acción 2019; Aemet 2018; Crane-Droesch and Marshall 2019; Masson-Delmotte et al. 2019) show that climate change results in a change of temperature and precipitation patterns resulting in higher frequency of extreme weather events like droughts, extreme rain and wind or temperature changes. The current levels are "are associated with moderate risks from increased dryland

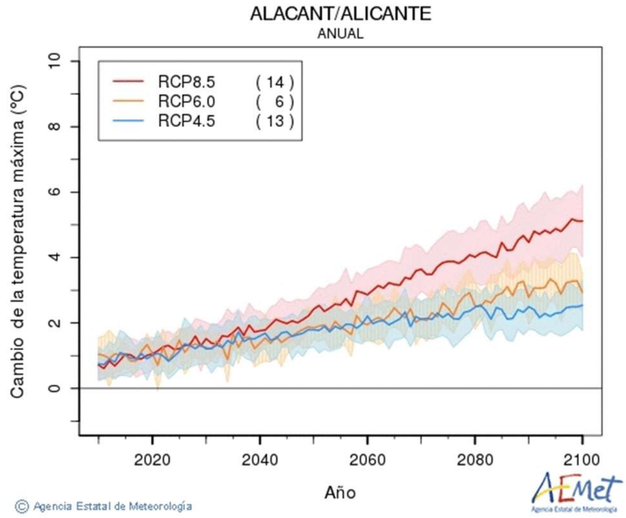


Figure 6 Increase of Tmax according to the three different scenarios RCP 8.5, 6.0 and 4.5 in the province of Alicante. An increase of 2-4°C is very probable according to the prospects (Source: Aemet 2021).

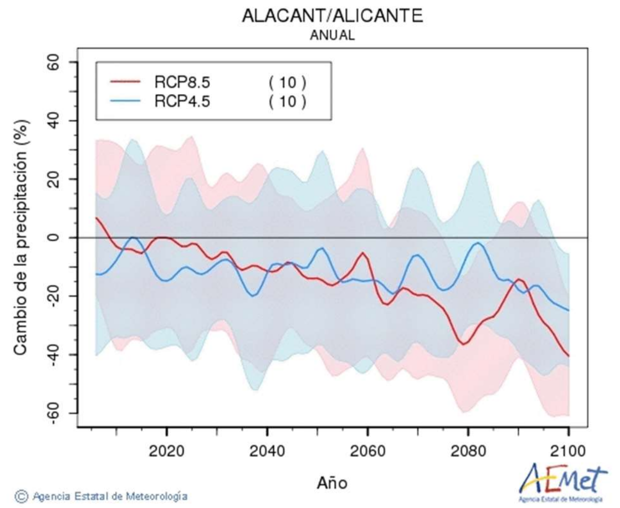


Figure 5 Prospected change of precipitation in the future due to climate change according to the two scenarios RCP 8.5 and 4.5 in the province of Alicante. Precipitation volume will decline in the worst scenario up to 40% (Source: Aemet 2021.)

water scarcity, soil erosion, vegetation loss, wildfire damage, permafrost thawing, coastal degradation and tropical crop yield decline (high confidence)" (Masson-Delmotte et al. 2019, p. 17), with five effects directly related with agriculture. As vegetation loss, water scarcity and soil erosion are already a problem of the province of Alicante climate change is very probably intensifying these issues in the future. Regarding the change of temperature the research of S.M. Vicente-Serrano et al. 2017 investigated the change of temperature in the Valencian community and found out that especially in the mountain regions a notable increase in the temperature has already occurred.

Water Scarcity and related **soil erosion** have always been part of this climatic zone and are not directly related to climate change (Morote Seguido 2020), but climate change is responsible for the intensification of it. As such water scarcity is not a natural disaster but rather an anthropological definition of lack of water for the planned use (e.g. agriculture activity with foreign crops in the case of the province of Alicante). Water scarcity is to be distinguished from drought as drought is based on meteorological parameter, while water scarcity depends on the demand and availability of water in a region. A reliable irrigation infrastructure as well as water management are crucial for efficient agriculture in this climatic area. The sudden and extreme precipitations provoked by climate change are more difficult to manage as frequent rain. As suddenly a huge amount of water must be collected, transported, and stored for the time of dryness. In the future less precipitation volume is very probable in the region (see Figure 6), while it will fall during shorter periods, challenging the irrigation infrastructure and provoking more soil erosion (Masson-Delmotte et al. 2019; Aemet 2021). Furthermore, this change of availability can result in more run-off water rather than recharging groundwater resources or surface water (which evaporates more because of the increase of temperature) and therefore stresses even more the fact of water scarcity in the region (Crane-Droesch and Marshall 2019).

The gap between available water and needed water in agriculture has been filled using groundwater. It is global phenomenon which happens mainly in arid, semi-arid and even humid regions tripling the use of non-renewable groundwater and thus dragging the problem off into future generations (Khadra and Sagardoy 2019) and not offering a sustainable solution to the main problems of Alicante's agriculture: **water scarcity, soil erosion, weather extremes** and **increase of temperature**.

2.2 Focus 2: Different practices of agriculture in the province of Alicante

In Spain agricultural practices have developed and adapted to the climatic circumstances in the region during many decades (Casas et al. 2014). The appearance and their share of the used practice have changed during the time according to the state of research, climate and state of the art of agricultural practices. The challenge of nowadays is to identify which agricultural practice or even which distribution of different practices can help to feed this region and at the same time protect the environment for future generations. The main differences are between irrigated vs. rainfed, greenhouse vs. open cultivation and organic vs. conventional cultivation.

Irrigated vs rainfed

As already discussed in the previous section the province of Alicante is a great agricultural producer but on the other hand has to fight with problems of water scarcity. In the line of intensifying agriculture and to increase crop yields a reliable irrigation is inevitable for the success of cultivation of some crops in the region. In 1997 49% of the cropland was irrigated, and up to 2019 the share of irrigated land increased to 57%. In total the land used for agriculture declined but in general the share of irrigated cropland increased (see Figure 7 and 8).

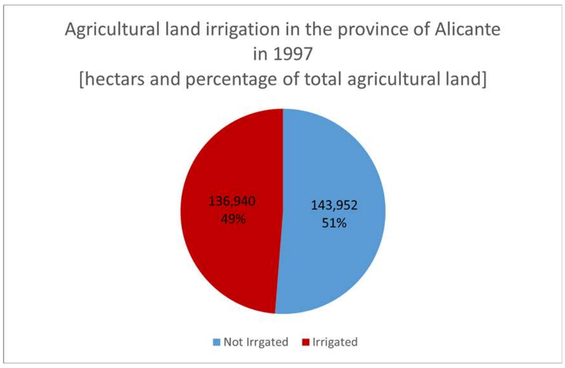


Figure 7 Hectares of agricultural land classified by irrigated and not irrigated farming in 1997 (Source: own elaboration with data from Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

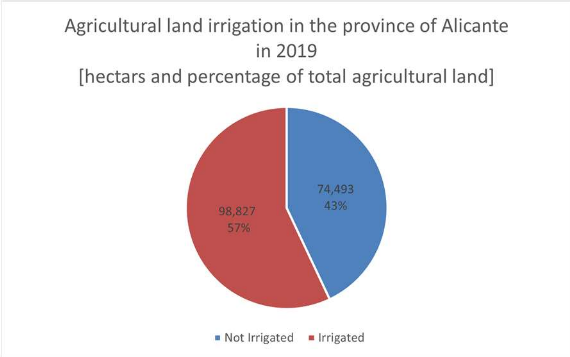


Figure 8 Hectares of agricultural land classified by irrigated and not irrigated farming in 2019 (Source: own elaboration with data from Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

The method of irrigation is crucial for water-saving and effective water supply to the plants. In the province of Alicante, four different irrigation techniques are distinguished: localized irrigation, surface irrigation using gravity, self-propelled irrigation and sprinkler irrigation (Ministerio de Agricultura, Pesca y Alimentación 2019). The most common irrigation method is the localized irrigation with 57 659 hectares, which shows a steady increase during the years (Ministerio de Agricultura, Pesca y Alimentación 2019). This method waters the plant directly at the roots and minimizes water loss (Holzapfel and Mariño 2008). Gravity irrigation has been gradually decreasing until it has lost great parts of the area, but still being the second most common irrigation method and used on 23 942 hectares (Ministerio de Agricultura, Pesca y Alimentación 2019). Sprinkler and self-propelled irrigation, only present in vegetables, cereals, forage and fallow land, are practically disappearing with 435 hectares (Ministerio de Agricultura, Pesca y Alimentación 2019). Especially surface irrigation using gravity results in high waste of water and soil erosion as the field is flooded for short periods. This way the water is not used as efficient as using localized irrigation (Holzapfel and Mariño 2008).

Irrigation helps to increase yields and therefore less land has to be used as agricultural land helping to mitigate climate change of limiting land use change. But at the same time is irrigation a factor which can provoke soil erosion and therefore important soil matter is lost (Dirección

General para la Biodiversidad 2006). This means more fertilizers are needed for cultivation. Irrigation and water management are on one hand the way how such an intensive agriculture can work in this climate zone, but on the other hand promote soil erosion with its damage for climate and biodiversity.

Greenhouse vs open cropland

Greenhouses help to increase the temperature using sunlight or heating systems and allow therefore the plantation of crops outside of their season. As an almost closed system it reduces the use of water and protects the crops from pests and diseases.

The use of greenhouses in Alicante is not as popular as in other regions of Spain. In 2019 only 1% (1 638 hectares) of the crop land was formed by greenhouses the rest is open cultivation (99%, 132,793 hectares) (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). The greenhouses are all irrigated information about organic or conventional farming practices in relation to greenhouses are not available. Considering the very limited use of greenhouses in this area make its effects neglectible.

Organic vs conventional

Agriculture has continued to evolve from a substance-based economy to an industry. It is not only due to technological developments and industrialization that agriculture has become more and more professional. Also, the increasing demand for food due to demographic growth, as well as a change in lifestyle, has led to an ever-increasing need for a wide variety of domestic and international agricultural goods. This culminated in the Green Revolution, when agriculture was completely industrialized (Gomiero 2018). The success of agricultural practices during this period was measured by economic indicators such as crop, crop per hectare, and profit. Environmental indicators played no role in the evaluation of agricultural methods during this period.

However, the negative effects on nature and the threat to biodiversity became apparent and a new movement began in the early 20th century as a countermovement. There, the extreme depletion of natural resources for agriculture was identified as unsustainable and more sustainable practices became popular again.

Organic agriculture refers to a practice where the environmental impact is considered, and long-lasting sustainability and conservation are valued. This means that soil fertility is preserved and the use of non-renewable resources limited to a minimum (Gomiero 2018). Furthermore, synthetic compounds, agrochemicals or genetic modified organism are strictly rejected. According to the International Federation of Organic Agriculture organic agriculture follows the four principles of **health, ecology, fairness** and **care** (International Federation of Organic Agriculture 2020). Underlining the wholistic approach organic farmers use (Gomiero et al. 2011). Organic farming seems to be a broadly used term to describe agriculture close to the environment but at the same time it is regulated by authorities (Seitz et al. 2019). As this idealistic view needs to be standardized to assure quality and transparency the European union and its countries defined some rules and standards for organic agriculture. In the valencian community the *Comité de d'Agricultura Ecològica de la Comunitat Valenciana* (CAECV) is setting the standard of ecological production and its certification for the region. The CAECV is the public law cooperation which is representing the government in the sector. Another important stakeholder in this region is the *Sociedad Española de Agricultura Ecológica/ Sociedad Española de Agroecología* (SEAE) a Non-Profit Organisation dedicated to training, development, and research in organic agriculture and in that sense shaping the landscape of ecological agriculture in Spain.

While the hectares used for cultivation have declined the ecological land use has inclined between 1996 to 2020 (see Figure 9). In 19 years the share of ecological land use has increased from 0,4% to 13,2% in 2016 with a trend promising to rise further in the future (Comité de d'Agricultura Ecològica de la Comunitat Valenciana 2020).

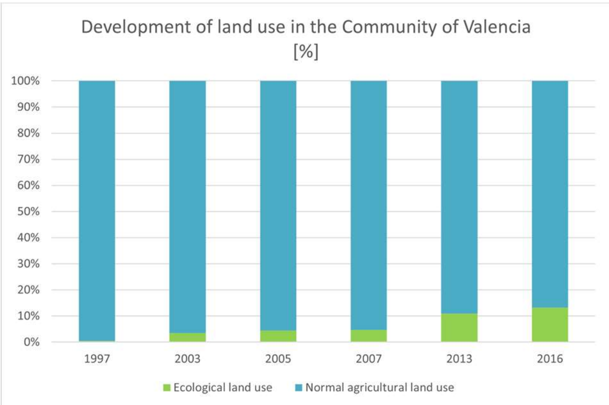


Figure 9 The share of ecological land use has increased between 1997-2016 with a clear trend of further incline (Source: Comité de d'Agricultura Ecològica de la Comunitat Valenciana 2020, own elaboration).

Since its objectives of long-term sustainability and perseverance of the environment organic agriculture is in the spotlight of various investigations regarding its possibilities to adapt or even to mitigate climate change.

Various studies (Reganold et al. 1987; Siegrist et al. 1998; Teasdale et al. 2007; Mitri et al. 2019) show that organic agriculture preserves the soil organic matter and therefore limits soil erosion, the big challenge of Alicante's agriculture (García-Orenes et al. 2012). With the vegetation cover and the moderate tillage often used in organic agriculture soil erosion can effectively be limited (Seitz et al. 2019; García-Orenes et al. 2012). This is promising that in case of more intensive rainfalls as expected due to climate change this agricultural practice can help to adapt to climate change. Furthermore, some studies have shown that crops of organic cultivations are more resistant to drought and have better water saving capacities (Bellon and Penvern 2014).

But organic agriculture is not only a way to adapt to climate change some studies suggest that it can help to mitigate climate change used as a carbon sink. Smith and Martino (2007) have calculated that around 20% of global annual CO_2 emissions could be reduced just with an adaptation of farming practices. Especially the potential of organic agriculture is tremendous as it emits between 46% to 66% less CO_2 as conventional agriculture (Ecologistas en Acción 2019) and binds more CO_2 due to its limited tillage and higher crop diversity.

The possibilities of ecological agriculture to be the possibility to adapt or even to mitigate climate change has been investigated on the big scale and seem promising. If this is applicable for the province of Alicante will be investigated in this thesis.

2.3 Focus 3: Evolution of the definition of Sustainability

Sustainable agriculture is an often-used term in politics and research, but the definition of sustainability and how it can be measured is part of ongoing debates. The term sustainability gained its great popularity in 1987 when, in the so-called Brundtland Report, the term sustainability was suddenly also discussed in a political context (WCED 1987). In this report sustainable development is defined as a development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 16). In this report sustainability has four aspects which are safeguarding long-term ecological sustainability, satisfying basic human needs, and promoting intragenerational and intergenerational equity.

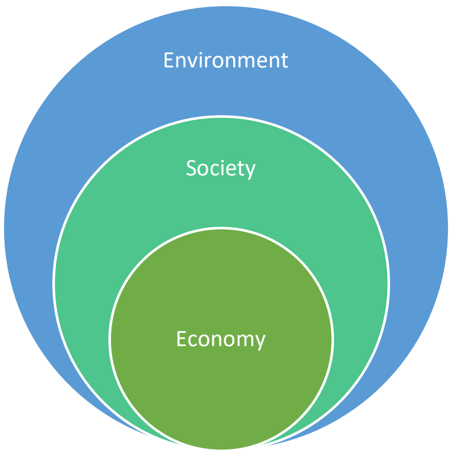


Figure 10 The three aspects of sustainability according to the UN General Assembly in 2005 (Source: own elaboration)

Sustainability at its core a very philosophical question; how we can shape our lives to leave the least harmful footprint possible. The concept of sustainability has since undergone a development that has always thrown a different angle on it. In 2005, at a UN summit, sustainability was defined in terms of three perspectives: social, economic, and environmental

(UN General Assembly 2005). In the future, the aspect of culture was also added. This is one of the best-known definitions of sustainability and is generally referred to. Sustainability is a systemic approach which cannot be assessed with a separated analysis as it sees the world as an interconnected system whereby activities have impacts on series of other areas (Gomiero 2018).

To make sustainable development more tangible and measurable the two very famous approaches of the **Sustainable Development Goals (SDGs)** and the **planetary boundaries** have been developed.

Figure 11 The 17 global goals for sustainable development as agreed on in the UN General Assembly in 2015 (Source: UN General Assembly 2015).

The **Sustainable Development Goals** are developed from the United Nations itself, which developed the Sustainable Development Goals as an evolution of the millennial goals in 2015. These goals set 17 global goals, which should promote sustainable development in the 193 participating countries (UN General Assembly 2015). The goals are based on the three aspects economic, social, and environmental sustainability (see Figure 11). Each goal comes with various indicators which try to make the progress on sustainable development measurable and even comparable between countries.

The selection and development of the indicators have generated a great deal of discussion. On the one hand, the SDGs were developed from a Europe-centric perspective and naturally also convey the impression that sustainable development is the result of a specific development path with concrete measurable and comparable indicators. This discussion about the measurability or not of sustainability, as well as the selection of the appropriate choice of indicators is very controversial (Piske 2019; Ziai 2017). Of course, a general and global understanding about the meaning of sustainability helps to bundle actions and thus lead to higher effectiveness. However, on the other hand, sustainability is always a very regional issue, depending on culture, geography, and economic activities. A universal recipe for sustainability is not easily possible and studies on the regional effectiveness of measures should always be more relevant than universal global statements. Agriculture is both very explicitly represented in the goals with its own targets and indicators, but is also implicitly reflected in other goals (UN General Assembly 2015).

Agriculture is both very explicitly represented in the goals with its own targets and indicators but is also implicitly reflected in other goals. The SDG 2 “End hunger, achieve food security and improved nutrition and promote sustainable Agriculture” with the target 2.4 especially a sustainable agriculture is promoted. The definition of sustainability in the context of agriculture is also difficult for the UN. Currently, no statistical data on the indicator measuring target 2.4 could be collected. The indicator of the share of sustainable agriculture in the total area of agricultural land was quickly decided. However, data collection was made more difficult because first it was necessary to agree on how to define sustainable agriculture and which areas had to be included in the statistic. An agreement was reached in March 2021 (United Nations 2021) and questionnaires with the objective to collect country data has been sent in late 2020. In the indicator, land use is classified in the form of a traffic light system (poor, acceptable and good). In addition, there are 11 sub-indicators reflecting the dimensions of economic, social, and environmental performance. This approach is strongly reminiscent of the definition of sustainability presented in the previous section.

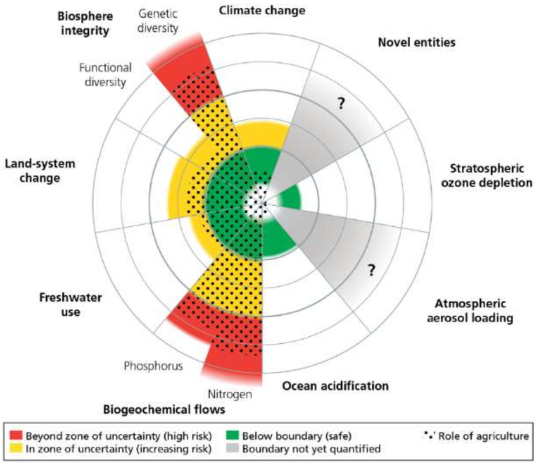


Figure 12 The planetary boundaries are a definition of sustainable development in a world with limited capacity (Source: Müller 2009).

Despite the regionality of the concept of sustainability, the world is closely interconnected due to globalization and, accordingly, local activities have global impacts. Since we all live together on the same planet and despite the capitalist idea that unlimited growth is important for a sustainable world, the theory of **planetary boundaries** has developed as a countermovement. The concept of planetary boundaries, as the title suggests, attempts to define the capacity limits of the Earth. It comes from Earth system research and essentially states that unlimited growth is not possible on Earth (Rockström et al. 2009). Exceeding these limits can lead to catastrophic and human-damaging conditions on the planet. Various scientists are striving to numerically identify the Earth's limits and based on the indicators, to give instructions for action to politicians and society, while at the same time defining a safe margin of action for humanity.

In total there are nine defined areas and three (Biodiversity loss, Nitrogen Cycle and Climate crisis) of them have already crossed the boundary for safe operating (See Figure 12) and agriculture plays an important role in these.

In summary, it can be said that the definition of sustainability is difficult and subject to constant change. Due to its very holistic and rather idealistic concept, it is difficult to define it in a universally valid way or even to make it measurable. Nevertheless, attempts to make sustainability measurable are made again and again in different contexts in order to coordinate international efforts or to promote political measures. The principle that the life of today should not restrict the life of future generations is reflected in all approaches. However, the exact implementation and translation into indicators is very different. A particular challenge in the context of sustainability is also the difference in the appropriate scale. Depending on the scale used, different statements regarding sustainability are correct. Spatial, cultural and economic differences also lead to different interpretations of the term sustainability.

3. Data and Method

To answer the question what agricultural practice can feed the region in a sustainable way, the research question must be assessed from different perspectives and with quantitative methods. In the following section the datasets used and the availability of data in general are discovered. Afterwards the methods used in this investigation to answer the research question and the limits of this thesis are explored.

3.1 Data

This investigation offers a more wholistic approach on the topic as it is not a merely quantitative research. The research question on the impact of climate change on the most common types of agricultural practices in the province of Alicante is assessed using quantitative methods first. But the discussion opens this narrow perspective to a broader understanding of sustainability. As sustainability is based on multidimensionality only this way a relevant investigation can be done.

The numeric data used for the investigation derives from open accessible data from public institutions of trust. In case various data sets about the same or very similar indicators have been available the data set was selected according to the completeness regarding the time and availability of metadata.

The main data sets used in this investigation are following:

Data Set	**Institution**	**Period covered**	**Published**
Organic agriculture in the Valencian Community	The Committee of Ecological Agriculture of the Valencian Community	1996-2020	2020
National soil erosion inventory (INES) *geospatial*	Ministry of Agriculture, Food and the Environment	2006	2006 (Alicante)
Information System on Land Occupation in Spain (SIOSE) *geospatial*	Ministry of Agriculture, Food and the Environment	2005,2009,2011,2014	2005,2009,2011,2014
Valencian Agricultural Sector Report	Regional Ministry of Agriculture, Rural Development, Climate Emergency and Ecological Transition	1997-2019 and for some items the values are missing for 2007-2014	1998-2006, 2015-2019
Climate projections for the XXI Century	State Meteorological Agency (AEMET)	2000-2100	2020

Table 1 Main data sets used for this investigation (own elaboration)

Whenever other data sets have been used in this investigation it is indicated accordingly.

To reach a certain standard only agriculture certified by the Committee of Ecological Agriculture of the Valencian Community (CEAV) will be classified as organic agriculture in this study.

In order to evaluate the effects of climate change on the different agricultural practices in the province of Alicante, climate-relevant data such as: maximum temperatures, minimum temperatures, number of days with nights below 0°C, number of extreme rainfall events per year, percipitation levels, duration of rain-free periods, and hail are considered. To relate this to the agriculture, agricultural parameters such as: volume of harvest, reported damage from meteorological events, land cover change, land productivity as measured in yield per hectar, soil erosion with its different types and the spatial distribution of crops are evaluated.

As already described in section 2.1 the province of Alicante is recognized as a province with various climatic zones, microclimatic differences, and high variety. To do justice to this aspect in the research, geospatial data were used with preference. With a total area of 5,816.5 km^2 (INE 2021), non-geospatial data regarding the influence of climate change on agriculture or vice versa lose their significance. Unfortunately, geospatial data is almost not collected or not publicly available and no geospatial data concerning different agricultural practices (organic or conventional) are available[1]. The only geospatial data sets used in this research are data sets of the **land cover** and **soil erosion**.

The Information System on Land Occupation in Spain (SIOSE) dataset was created using satellite data and aerial photographs, while the Valencian Community Agricultural Annual Report is based on the reporting data available to the Ministry at the time[2]. The resulted in sometimes very dramatic differences in the areas with specific land use. On the one hand, non-agricultural production (such as private cultivation) is also classified in the geospatial data. In addition, areas can also be misclassified or not reported.

There has also been a change in categorisation or methodology in the data sets over the years. In the Valencian agricultural sector report great shifts on the number of specific categories can

[1] Some data is publicly available for viewing, but it is only made available for scientific analysis and further processing after a formal request. Several formal requests, as well as numerous attempts to contact the relevant authorities by phone or email, were unsuccessful. Especially the contact with the Regional Ministry of Agriculture, Rural Development, Climate Emergency and Ecological Transition or the Cartographic Institute of Valencia was very disappointing. As data is apparently available for viewing, however, the relevant persons who could provide it for statistical analysis did not respond to several attempts to contact them. With the online data visualiser, scientific processing was not possible, as either the legend or metadata were missing and thus only a very rough assessment was possible.

[2] Another factor that strongly affected the statistical analysis of the data was that the data was quite often published in separate Excel lists or even only in reports in pdf format. Thus, annual developments had to be painstakingly collected from individual publications and sometimes even typed out by hand. Raw data for further statistical processing was only available in very rare cases. However, the analysis of changes over the period was very important and the necessary data was collected from the publications.

be seen on consecutive years. They seem rather methodological than a reflection of real developments in the agricultural sector, for example the surface covered by greenhouses changed between years extremely (1994: 106ha; 1995: 597ha; 1996: 60ha). As this is long ago and meta data is not available for this data its validity is hard to proof. Some data points are just missing (for example the amount of cultivated grapes in the year 2014 published by the Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019) or the great data gap of unpublished agricultural reports for the period of seven years (2007-2014). The categorisation of items changed over time and makes it hard to evaluate it precisely over time. As in some years the crops have been assessed very detailed and in other years the figures have been summarized to larger categories.

Research has been constrained mainly by the availability of the data and its quality. Since, above all, data over a long period of time are necessary in order to evaluate climatic influences, a separate survey during the research period was not possible. The method for data collection and the completeness of the data sets over the period was unfortunately not given for many environmental parameters, which is why this research then had to be limited accordingly. The restrictions mainly concern the selection of the environmental parameters and the development of these over a longer period of time. Since, for example, only data for the year 2005 are available with regard to soil erosion and accordingly no developments could be examined. The lack of data on various agricultural practices also limits this research.

Although the data sets used cannot meet the highest quality standards, they are the best available. With regard to the few limitations regarding quality, completeness and comparability as described in this section, they are nevertheless considered of sufficient quality for this research.

3.2 Method

This work aimed at developing a systematic approach for assessing land degradation at the subnational level with the combined use of geo-spatial information and statistical data. The research question was investigated using quantitative methods like trend analysis, histograms, development over time and distributions, while a large part of the research work is the preparation and processing of the data sets. In this research, a deductive approach was taken to verify whether organic farming is indeed a sustainable option for the province of Alicante.

For the study of climate change impacts on different forms of agriculture and their potential to increase the resilience of agriculture to climate change, statistically collected data from official sources (see section 3.1) and, if available, with geospatial reference are used. The methodology on the processing and the possibilities of analysis of the data sets depend on the availability of geospatial referencing.

Statistical data from reports

The Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica publishes an annual report on the agricultural sector in the Valencian Community. This data is available for download on their webpage in form of annual excel sheets.

In the first step, all available reports were reviewed to identify the relevant parameters. In the reports, which were up to 12 chapters long, between 10-15 parameters were identified as relevant, depending on the year and classification used in the report. The parameters include various parameters that describe land use, as well as agricultural techniques (greenhouses or artificial irrigation). But also, parameters that provide information about the quality of land use, such as the value of the harvest and the quantity of the harvest.

The relevant parameters were compiled from the various reports in order to be able to take a better look at developments over the years. Graphs of the individual parameters were then created using Excel to enable a **visual analysis** of the data and to identify special features. **Trend analyses** were also made using Excel to identify possible trends in the development of certain parameters.

To determine possible correlations in the development of different parameters, visual analysis was also carried out by visualizing the data together in a graph.

Geospatial data sets

The spatial data provide more detailed information regarding their parameters. This means that regional differences can also be analysed. With regard to the processing and analysis of the data, however, this is also associated with more effort. For processing and analysis, QGis (version 3.14) with the plug-ins R and SAGA was used. While QGis offers the methods for processing the data, the plug-ins enabled a better statistical analysis of the data.

The available datasets were downloaded and screened based on their attributes table. To determine statements regarding regional differences, the data sets were trimmed according to the provinces using the clip tool. With the help of the corresponding metadata, the coding of the different classes could be decoded. The data were filtered with respect to their classification and new layers were created for the relevant classes. The classes of land use were made for better comparability based on the classification of agricultural products in the annual reports of the agricultural sector in the Valencian community. Furthermore, only the polygons with a minimum of 50% of the crop type is included in the research. If the cultivation was less than 50% a major impact of the soil is not expected.

The resulting maps of land use were **visually analysed** to discover noticeable trends over the years. They were analysed in different scales (community, province, municipality), different classes (crops, erosion types…), and different years (2005-2014). With the help of the formation of classes and the different colouring in the map, for example, different intensities of erosion or land use changes can be shown.

The different datasets could be **linked** in terms of their georeference or a common ID to obtain more information. For example, the data sets on erosion, as well as certain crops could be linked, and possible correlations could be revealed. In the case of the erosion data set which covers 2006 only, it has been linked with the SIOSE data set on land use from 2005 as this are the closest times available. This results in minor uncertainties.

By summing up certain data points, total areas with certain properties or percentages of certain areas of a total unit can be identified. For an overall impression of the distribution of certain classes, **histograms** are considered for raster data sets.

<u>Analysis regarding organic or conventional agriculture</u>

As described, very few data sets are available on different farming practices. Data on organic agriculture are not georeferenced and, in this context, a spatial analysis is not directly possible. The same is true for irrigated or non-irrigated fields or tillage practices. Only data on crops are available. However, there are data in the annual informs regarding the **proportions and developments** of organic and conventional cultivation per crop or how much area of a certain crop is irrigated or not. These data can provide a reference to the possibilities of adaptation or mitigation to climatic events if the developments are put in connection. This will be done along the effects which are expected to intensify in the future because of climate change, like soil erosion, extreme weather events and temperature changes.

For the main crops citrus fruit trees, other fruit trees, olives, and grapes a further analysis of the laminar erosion and the mass movement is done. Due to its particular importance in terms of land conservation, fallow land, as well as meadows and pastures are also analysed.

4. Results

Ways of mitigation and adaptation of climate change in the agriculture must be assessed regionally as some activities can be sustainable in one region but in others now. In this research a quantitative analysis on the possibilities of adaptation and mitigation of the effects on climate change in the region are assessed and later brought into context of sustainability. Because for a climate-friendly agriculture which feeds a region it is important to develop sustainable strategies, which are good for the environment, economy, and the society. In the province of Alicante agricultural practices have changed over time and in general have lost diversity compared to the beginning of the studied period.

4.1 Greenhouses and biodiversity

Greenhouses have been used in agriculture since ancient history and in the province of Alicante they appear since 1889 in public statistics (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). In the studied period between 1989 and 2019, one can see a rapid increase of greenhouses with a steep inclination of 55,5 hectares per year according to the linear regression (see Figure 14). While in 1989 only 185 hectares of greenhouses were established, at peak times the figure was 1,863 hectares (2012). After that, a rapid decline is noted, which, however, shows an upward trend again in the last year 2019 (2018: 1,538 hectares; 2019: 1,638 hectares) (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). The production in greenhouses has the advantage that resources like water and sun light are better managed. Greenhouses are completely or partly closed systems which reduce the loss of water through evaporation and therefore reduce the water needed for irrigation (Bergstrand 2010), one of the biggest challenge in the province (Sanchis-Ibor et al. 2019). Greenhouses expand the crops' seasons and allow more yields on less agricultural land (Pardossi et al. 2004), favouring a decline of agricultural land. Furthermore, by shielding the plants from the outside world plagues and diseases can be better warded off and pesticides are used less frequently or, if necessary, very specifically to fight a specific pest or disease (Antón et al. 2004).

Greenhouses can be divided in the northern-type with a high level of technology and optimization and the southern-type which are more economic and less efficient systems, usually just like plastic-covered land (Castilla 1994). The advantages of greenhouse cultivation depend heavily on the type of greenhouses used. Though in the statistics there is no further indication of the type of greenhouses used in the province it can be assumed that the majority are of the southern type (Bergstrand 2010). The southern type of greenhouses are rather open systems as the plants are communicated with the surrounding area through the soil. Especially groundwater leaving the greenhouse can have a negative impact on the environment (Castro et al. 2019). The intensive form of cultivation done in a greenhouse requires the application of fertilizers to provide the crops with the needed nutrients. The highly dosed fertilizers can leave the system with the irrigation through the groundwater and provoking environmental damages in the surrounding area or even reaching up to the sea (Marcelis et al. 2000). Another challenge is the strong interference with nature that greenhouses bring. The ecosystem is strongly cut by a greenhouse and a new ecosystem is formed in the greenhouse, with the greatest possible independence. The biodiversity in a greenhouse is very low and in the surroundings of greenhouses the biodiversity is affected. Greenhouses can block animal migration routes, interrupt ecosystem communication, and have an impact on the climate conditions to neighbouring areas (Bergstrand 2010).

Greenhouses offer the opportunity to plant as efficiently as possible and save space. The environment can be controlled as correctly as possible for efficient plant growth, allowing for the highest quality crop on the least amount of arable land. Having a positive impact on climate change and biodiversity as less land must be converted into agricultural land. However, greenhouses that are not fully enclosed pose a risk to the environment. They lead to extended harvesting times and environmental pollution, which are rather harmful and promote climate change.

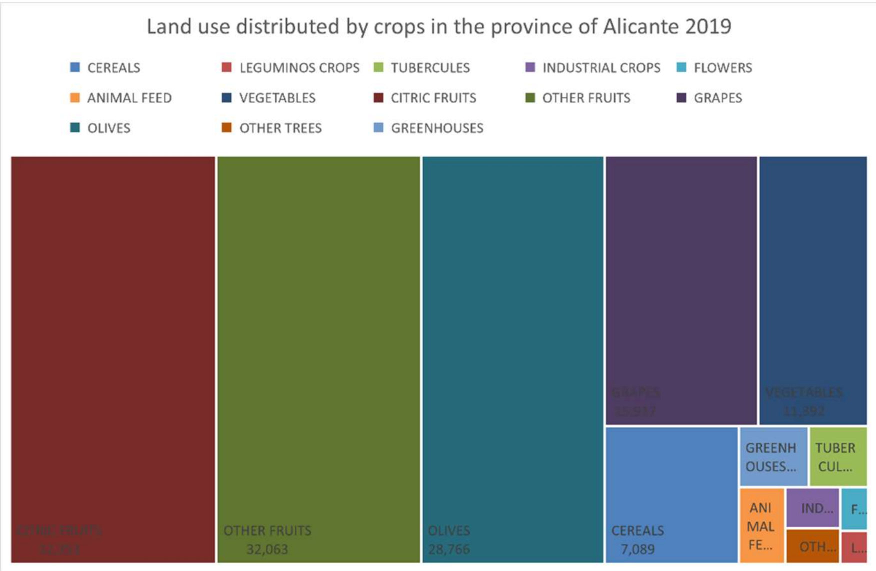


Figure 13 Diversity of crops in the province of Alicante in 2019 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

The intensification of agriculture and the high specialisation resulted in a loss of biodiversity in the province of Alicante. Not only through the land use change which decreased the habitat of many species, but diversity in the crops used for agriculture has declined dramatically (Campbell et al. 2017). In the province of Alicante the main crops cultivated are citrus fruits, fruit trees in general, olives, grapes, and vegetables (see Figure 13). The modernisation of agriculture shifted the crops from regional products to water demanding but more profitable crops for the export market. This loss of diversity has a risk in regard of the mitigation of climate change, as regional plants are better adapted to the regional climate and therefore less sensitive to the developments expected from climate change (Masson-Delmotte et al. 2019). The problem of the cultivation of water intensive crops in this semi-arid environment will be discussed in the following section.

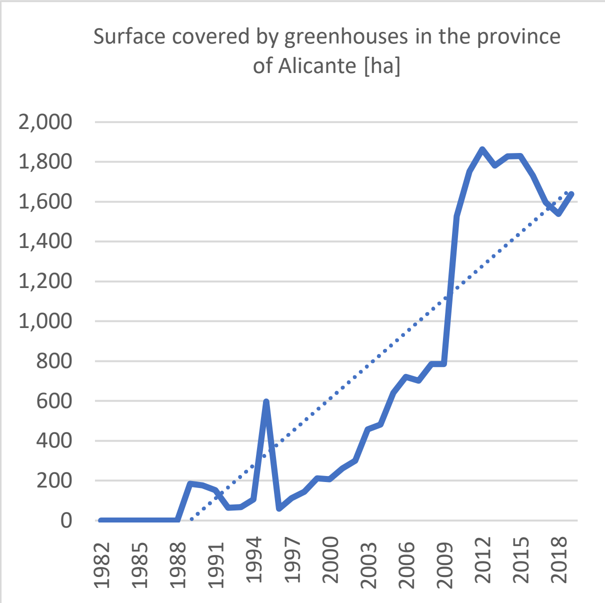


Figure 14 Hectares of agricultural land in greenhouses in the period 1982-2019 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

In summary, greenhouses offer a huge potential for climate change adapted agriculture in the sense of offering further control over the plants growing environment. However, the southern type of greenhouses is not suitable because of the high pollution of the environment and not sufficient control. Modernization and cultivation in a closed system would be better option from an environmental point of view but would also require higher investments and modernization works. But nevertheless the opportunities and threats of greenhouses to preserve biodiversity and use them for a climate-friendly agriculture depend mostly on the crops selected and the technologies used.

4.2 Irrigation and water use

While the total agricultural land has declined from 280,892 hectares (1997) to 173,320 hectares (2019), the share of irrigated land has increased from 48,75% (1997) to 57,02% (2019)

(Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). Both irrigated and not-irrigated land has declined, but not-irrigated land much more than irrigated land (see Figure 16). This is a result from the intensification of agriculture and the better access to irrigation infrastructure (Khadra and Sagardoy 2019). In the last 20 years enormous subventions from the Spanish government helped in modernizing and expanding the irrigation system and further investments are planned (Khadra and Sagardoy 2019; Planes estratégicos territoriales de carácter supramunicipal 2005, The). The investments are justified with the explanation that "their implementation with the water savings they will achieve. It is true that the water savings at the farm level are quite large, and around 25% are reported in Spain […]. However, the irrigation returns—that are utilized by other users downstream- are reduced and therefore, the net saving at the basin level is generally smaller. In Spain, it is around 12% (Khadra and Sagardoy 2019).

Furthermore, the savings are often used to produce crops with higher water requirements" (Khadra and Sagardoy 2019, p. 110). The idea behind the modernization is great to decline the water loss in the irrigation system, but if the saved water is later used for more water intensive crops it does not help to recover the groundwater bodies. The extreme water demand paired with the increase in agricultural production resulted in the risk-status of 37% of groundwater bodies in Spain (Berbel et al. 2018). Summer month are especially dry in south-eastern Spain but at the same time summer is the main cultivation season as well. During summertime the water used for irrigation reaches its peak, because "45.5% of the annual total is used" (Torregrosa and Sevilla 2010, p. 4) this time.

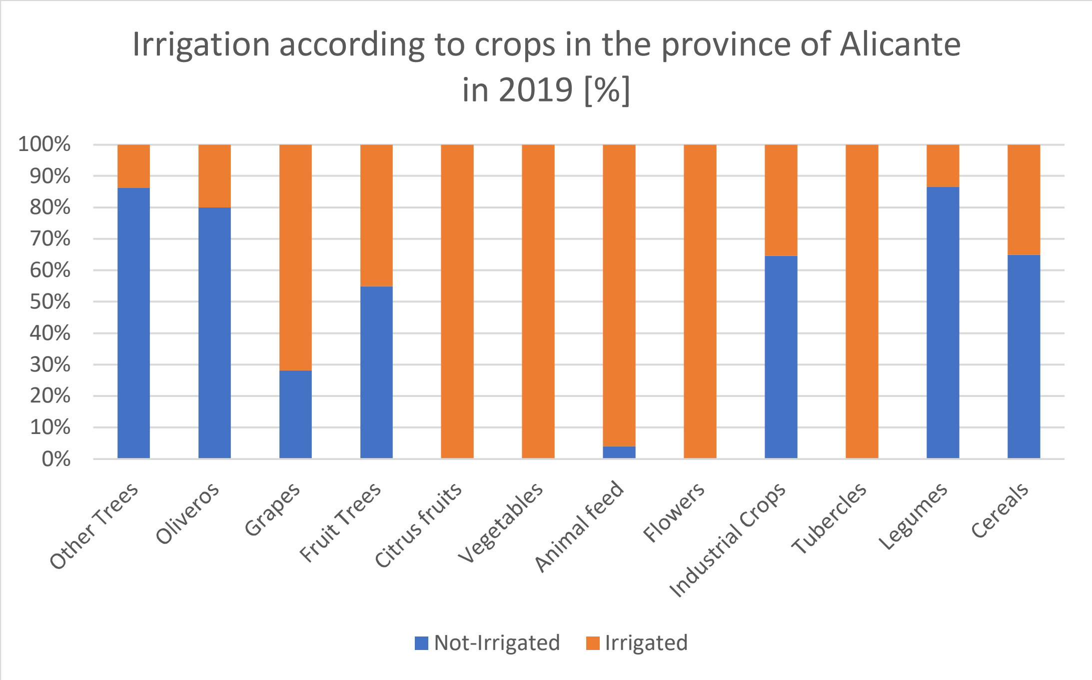


Figure 15 Irrigation of cultivations for different crops in the province of Alicante in 2019 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

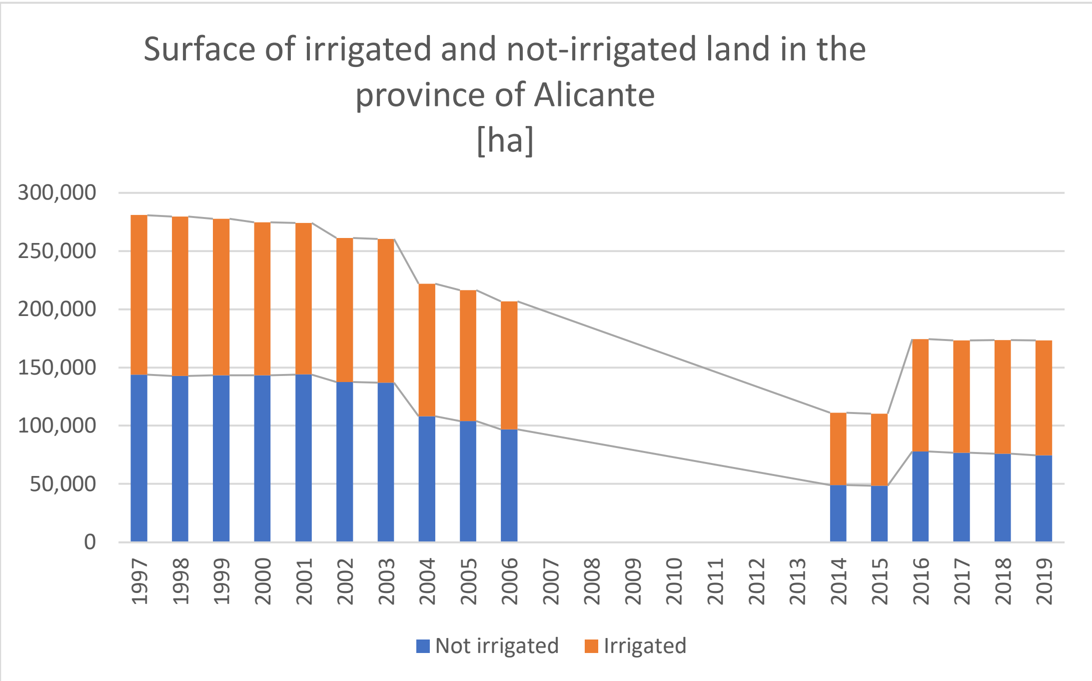


Figure 16 Hectares of irrigated and not-irrigated land in the province of Alicante in the period 1997-2019 (Source: (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019), own elaboration).

Climate change is expected to change the availability of water for irrigation therefore a highly efficient irrigation system with a minimum to water loss must be installed. With the prospected decline of precipitation volume of around 10-20% in the next 10-20 years water scarcity will increase dramatically in this region, where it is already a problem (see Figure 17). At the same time heatwaves will last longer (see Figure 18). This results in higher evaporation for plants, higher transpiration rates of water bodies and furthermore putting more stress on water reserves. If saved water is used for further use further down the stream and to plant more water intensive crops the benefits of a modernized irrigation system equal almost null. Temperature and soil conditions in the province of Alicante are favourable for the cultivation of nuts, fruit trees and vegetables which are water demanding crops, but on the other hand very profitable (see section 4.1). The high-water demand of the main crops can only be covered with irrigation in the case of vegetables, flowers, tubercles, and citrus fruit all cultivations are irrigated (see Figure 15). There is not a single crop whose yield cannot be increased through irrigation and therefore we find irrigation in all crop types with a share of minimum 10% irrigated cultivation.

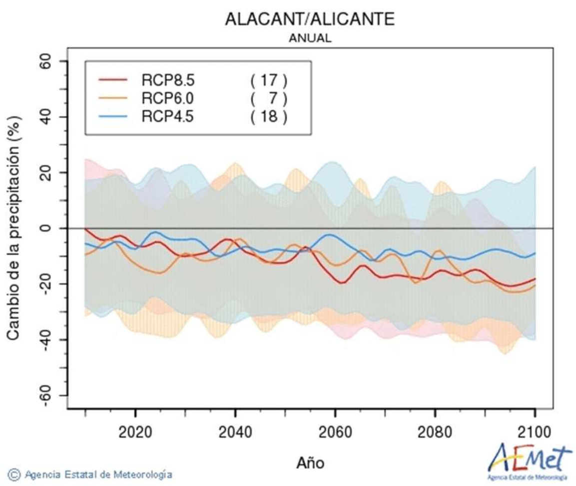


Figure 17 Prospected change in precipitation volume in the period 2000-2100 (Source: Aemet 2021).

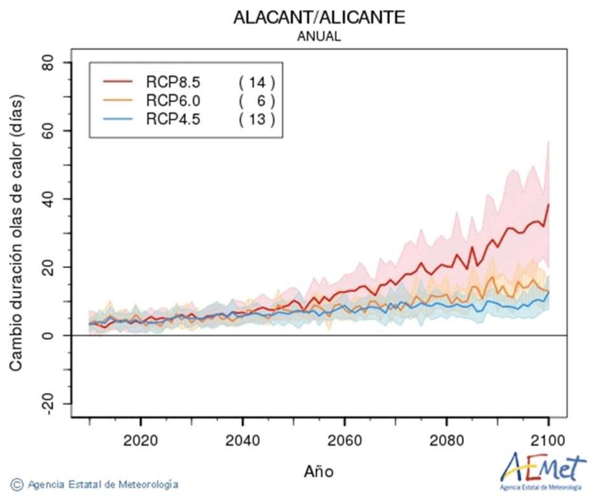


Figure 18 Prospected change of length of heat waves in days for the period 2000-20100 (Source: Aemet 2021).

Not only the reduction of precipitation volume in the region will put more pressure on the groundwater bodies and the water availability in general (Meseguer-Ruiz et al. 2017). Higher temperature increases the evaporation of the plants and therefore water demand of the plants increase. At the same time open water bodies and runoff wate evaporate more and less water filtrates and refills the groundwater bodies (Moutahir 2016). Water scarcity dries up the soil and infiltration rates decrease dramatically. So the general warming trend in this province puts extreme pressure on water availability (Torregrosa and Sevilla 2010; Calvache et al. 2018).

Another important aspect to consider is that Irrigation systems and the modernisation work itself increased the demand of electric energy up to 657% during the period 1970-2007 (Khadra and Sagardoy 2019), creating another big impact on climate change in a country where only 18,36% of the energy is coming from renewable sources (EUROSTAT 2020).

The intensification of agriculture and the expand of irrigated land pose an enormous risk regarding climate-friendly agriculture (Khadra and Sagardoy 2019). The increasing demand for water is exacerbated by declining precipitation and rising temperatures. There is already a huge water problem in the region with intense resource conflicts (Olcina Cantos et al. 2016). The modernization of the infrastructure to stem water losses may seem like a good idea at first glance, but it must be remembered that the high energy consumption, as well as the increased consumption of water due to better availability, will reverse the progress (Torregrosa and Sevilla 2010). A clear paradigm shift is required on this point. Besides the problem of extreme water scarcity, irrigation is one of the main causes of soil erosion (Gafforov et al. 2020). A major risk, which will be examined in more detail in the next section.

4.3 Land use and soil conservation

The sustainability and resilience of an agricultural practice depends heavily on its ability to conserve soil. This is because erosion in particular leads to the removal of the organic masses that preserve the nutrients for the plants and have high water saving capacities (Teasdale et al. 2007). In addition, the soil stores water over a longer period and makes the plants more resilient to heat waves. Different agricultural practices have different protective or destructive forces on the soil.

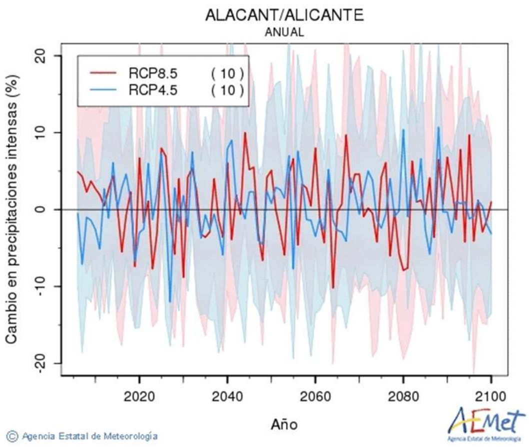


Figure 19 Prospected change in annual intensive rain events in the period 2000-2100 (Source: Aemet 2021).

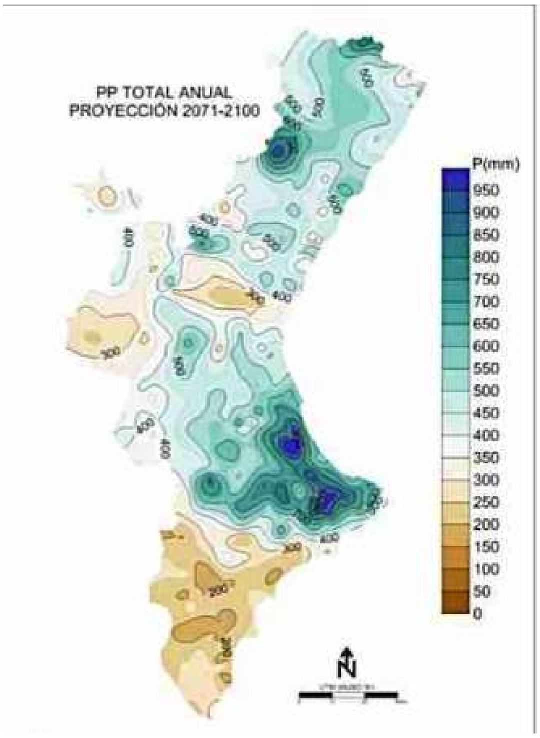


Figure 20 Prospected annual precipitation in the period 2071-2100 in the Valencian community (Source: Miró et al. 2016).

In the province of Alicante, intense rain events occur regularly (Olcina Cantos and Moltó Mantero D.L. 2019), which can cause severe erosion, especially in dry soils. In particular, the upper nutrient-rich layers are washed away. They are especially hard to control as they are not frequently in the same season like in the case of monsoon or rain times in other climatic zones (Olcina 2017). The study of Meseguer-Ruiz et al. (2017) investigated the increase in this intensive rain events during the course of the time and as well in the future. Intensive rain events have increased, while the trend is going further upwards (see Figure 19). With the incline of intensive rain events wash-offs are increasingly likely in the future (Gafforov et al. 2020). While it has been discussed that in general precipitation volume will decline in the province of Alicante Figure 20 gives a more detailed insight into the change of precipitation patterns for the Valencian community. As intensive rain events will increase in some regions it comes to a higher amount of precipitation volume, but this occurs very local and in form of intensive rains, making it a natural hazard and harder to fetch for agricultural use.

In the research paper of García-Orenes et al. (2012) it is stated that soil erosion is especially intense in irrigated citrus cultivations and vineyards. Irrigation, tillage as well as uncovered fields show the highest risk of erosion (Seitz et al. 2019; Teasdale et al. 2007; Siegrist et al. 1998). The increasement of irrigation practices are discussed in the section 4.1.2, while reduced tillage and soil covering as practiced in organic agricultural farms, will be studied in this section.

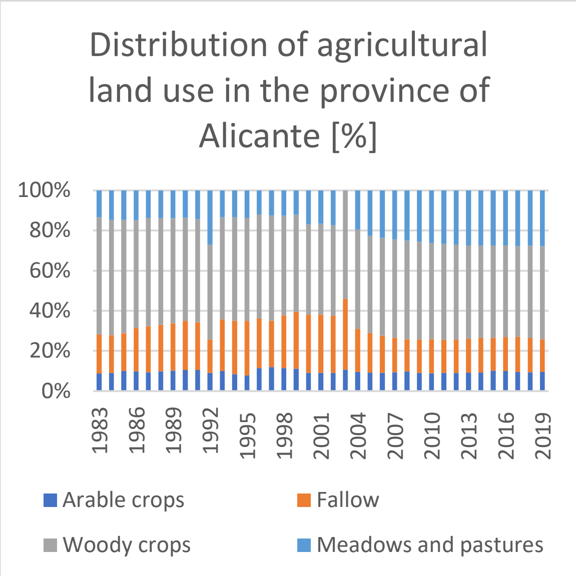


Figure 21 Distribution of agricultural land use by the categories arable crops, woody crops, fallow and meadows and pastures in the province of Alicante between 19983-2019 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

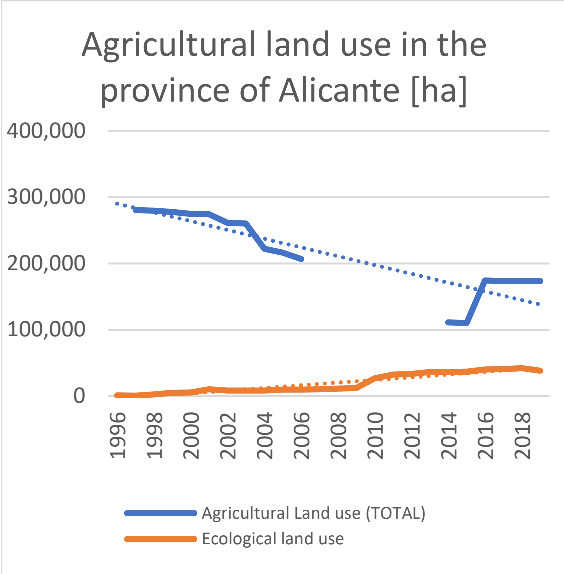


Figure 22 Development of total agricultural land use and ecological land use in the province of Alicante (Source: Comité de d'Agricultura Ecològica de la Comunitat Valenciana 2020; Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

In general less tillage results in less soil erosion regardless of whether organic or conventional farming is practiced. (Seitz et al. 2019). Vegetation cover helps to protect the soil by rain from erosion. This makes fallow land especially erosive. But while the share of arable cropland has remained almost unchanged (2019: 22,9 hectares), fallow land has declined by 43,3 hectares from 1989 (82,2 ha) to 2019 (38,9 ha) (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). At the same time meadows and pastures have increased from 48 ha (1989) to 66,5 ha (2019). Meadows and pastures protect the soil and give the field time to recover (Gomiero et al. 2011). They save water, are important habitats for many species and therefore help to protect biodiversity.

The National Inventory of Soil erosion a study conducted by the Dirección General para la Biodiversidad in the year 2006 gives some interesting insights into the soil erosion of the province of Alicante. The erosion is classified by 9 categories, while categories 1-3 are not harmful erosions, 4 and 5 are harmful, 6 and 7 are very harmful as they do not allow the environment to recover itself. The categories 8 and 9 are not interesting as they describe artificial surfaces and open water bodies. The study investigated the Aeolic erosion, laminar erosion, gully erosion, riverbed erosion and profound mass movements. Aeolian erosion is not significant because its values do not exceed 10t/ha/year (category 3) and thus have no negative impact on the environment (see Figure 23). In the agricultural context, laminar erosion and profound mass movement are still important. The corresponding data are examined by crop.

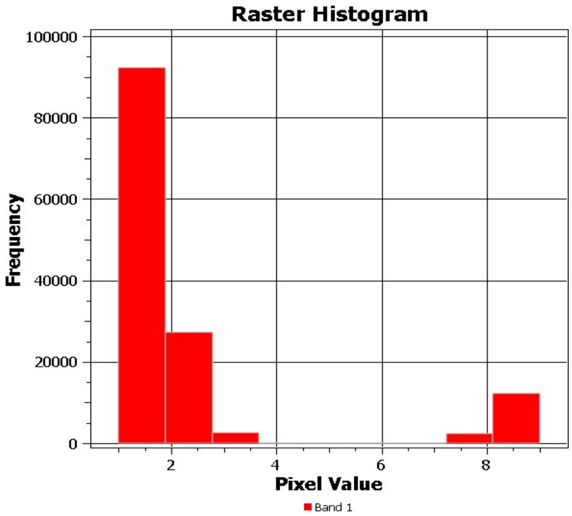


Figure 23 Raster Histogram of the Aeolic erosion in the province of Alicante in 2006 is not harmful (Source: Dirección General para la Biodiversidad 2006, own elaboration).

Role of organic agriculture in soil conservation

Another agricultural practice which is characterized by a particularly soil-friendly cultivation is organic farming. Various studies have already investigated the potential of organic farming in minimizing soil erosion (Gomiero et al. 2011; Siegrist et al. 1998; Teasdale et al. 2007).

In the province of Alicante, the percentage of arable land cultivated organically is continuously increasing. While agricultural land use declines with a rate of 6624,3 hectares per year increases organic agricultural land with a rate of 2029,8 hectares per year (see Figure 18). This trend suggests a decrease in erosion in the province of Alicante as the proportion of agriculture that protects the soil increases. Unfortunately, no data are available on the historical evolution of soil erosion in the province.

But also, when looking at the crops where organic farming is used, it can be seen in Figures 24 and 25 that it is precisely in crops where high soil erosion has been observed (citrus fruits, grapes, and vegetables) (García-Orenes et al. 2012) that organic farming represents the largest share, which offer a great opportunity to minimize erosion in the most affected cultivations.

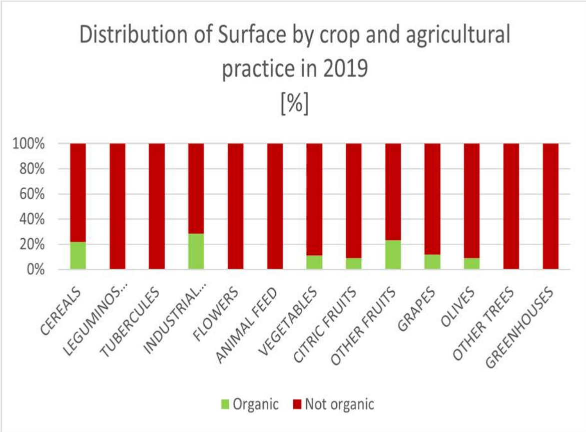


Figure 24 Share of organic agriculture by the cultivation of different crop types in the province of Alicante in 2019 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019).

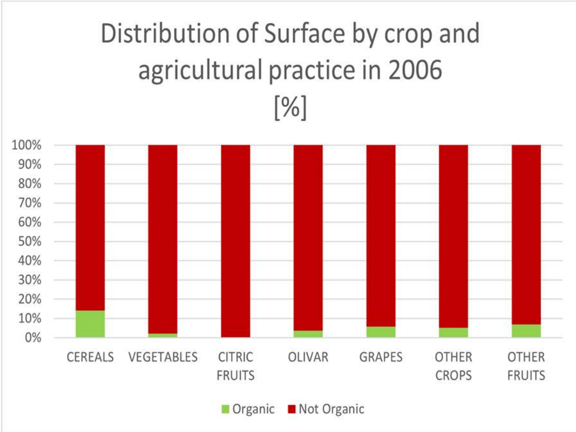


Figure 25 Share of organic agriculture by the cultivation of different crop types in the province of Alicante in 2006 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019).

For the main crops citrus fruit trees, other fruit trees, olives, and grapes a further analysis of the laminar erosion and the mass movement is done. Due to its particular importance in terms of land conservation, fallow land, as well as meadows and pastures are also analysed.

Citrus fruit trees

Citrus trees are the second most widespread type of cultivation in the province of Alicante in 2006 according to the annual report (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). In the data set of SIOSE 2005, a total of 196 167 hectares are used for the cultivation of citrus fruit trees and they are the third most common land use type of the nine investigated types. This is much more than the 36 523 hectares reported in the annual agricultural report of the Valencian community in 2006. The main difference between the two datasets is the data collection and classification (see 3.1).

Cultivation takes place mainly in the southern and northern zones and near the coast. Since citrus fruits need to be irrigated, they are more likely to be found in the lowlands and not on slopes or hills.

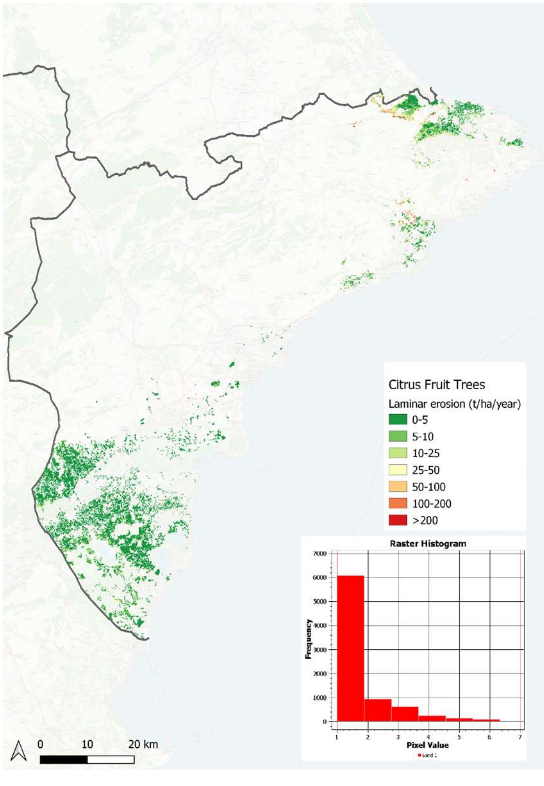


Figure 26 Laminar erosion in cultivations of citrus fruit trees (own elaboration).

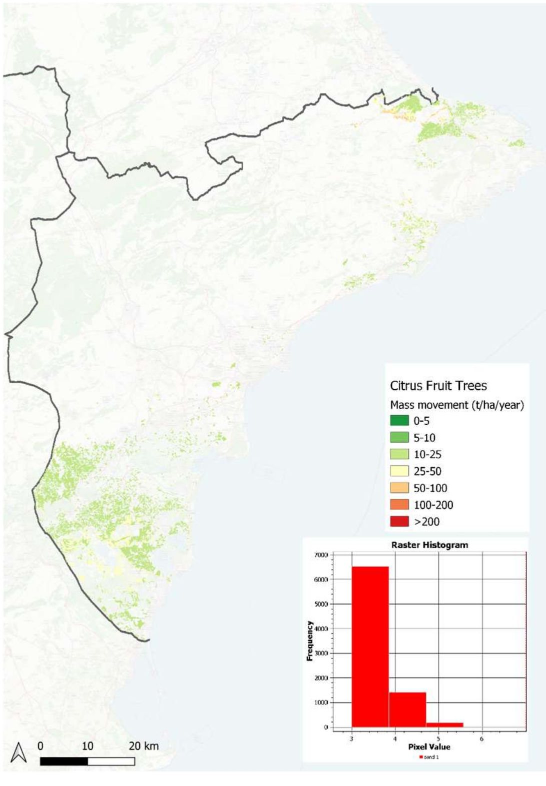


Figure 27 Erosion by mass movement in cultivations of citrus fruit trees (own elaboration).

Around 35 367 hectares are affected by laminar erosion, which makes 18% of the total cultivated area. Though García-Orenes et al. (2012) study resulted in high erosion values for citric fruits this cannot be confirmed for the province of Alicante as in comparison to the other land uses the share of erosion (laminar and mass movement) is relatively low (18% and 18%), especially in regard of the high risk erosion (0.2% and 0.3%). In this data sets it has the least share of erosive surface from all studied types. The biggest area of 26 524 hectares (13,5% of the total cultivation area) is only erosion category 1. Both forms of erosion occur more frequently in the northern growing region.

	Coverage of cultivation in ha	*Laminar Erosion*	*Surface of erosion category 6 and 7*	*Erosion by mass movement*	*Surface of highest erosion category 5*
in ha	196167.3	35366.8	378.25	35366.9	614.9
in % of total cultivation	-	18.0	0.2	18.0	0.3

Table 2 Overview of erosion in citrus fruit tree cultivations (own elaboration).

In general, the cultivation technique for citrus seems to be comparatively good with regard to soil erosion. However, agricultural use is the main cause of erosion and also in the case of citrus fruit trees 1 844 hectares (categories 4-7) are threatened by erosion and appropriate measures must be taken.

In 2006, only a minimum of citrus cultivation was done within the framework of organic farming (0.24%) (Dirección General para la Biodiversidad 2006). This means that the influence of organic farming in terms of erosion control in lemon trees should be considered irrelevant. Even if no comparative data are available, the erosion values are very low even with almost exclusively conventional agriculture. In the absence of data on the spatial distribution of organic agriculture, it is impossible to assess whether there is a relationship between the type of agriculture and erosion. Whether there is less organic agriculture in the north of the province of Alicante and this is a reason for the higher erosion or whether other factors lead to it needs further investigation.

The cultivation of citrus trees is critical for sustainable agriculture in terms of climate projections, especially in terms of their high-water demand and biodiversity. From a soil conservation perspective, they are not at risk from the extreme events of climate change in the context of the factors investigated in this research.

Fruit trees (excluding citrus fruit trees)

Other fruit trees than citrus fruit trees are most common crop type according to area covered in the province of Alicante in the year 2006 (Dirección General para la Biodiversidad 2006). In the annual agricultural report of the Valencian community 38 604 hectares are dedicated to the cultivation of fruit trees. In the SIOSE data set 159 081 hectares are classified as fruit tree cultivations excluding the cultivation of citrus fruit trees. In comparison to our other nine investigated land uses this is the mayor area by crop type only meadows and pastures cover more area.

As the category sums up various crops the cultivation area is all over the province of Alicante without regional focuses. The main fruit trees other than citrus fruit trees are almond trees and other nut trees.

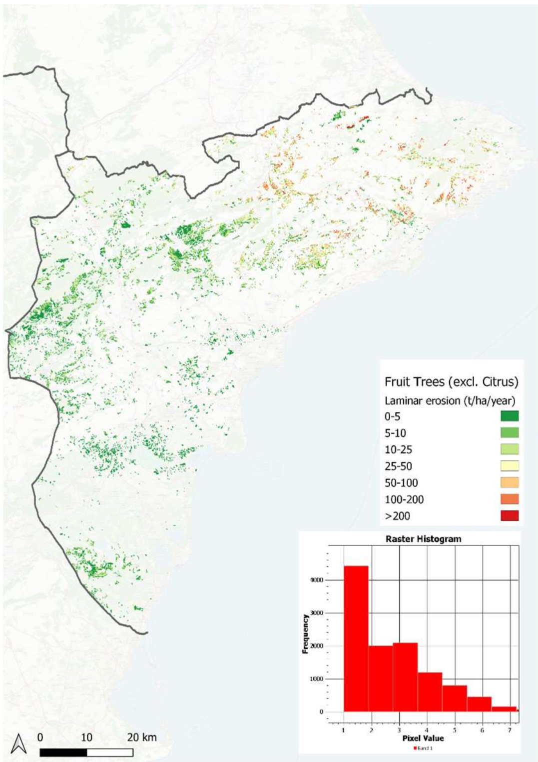


Figure 28 Laminar erosion in cultivations of fruit trees (excluding citrus fruit trees) (own elaboration).

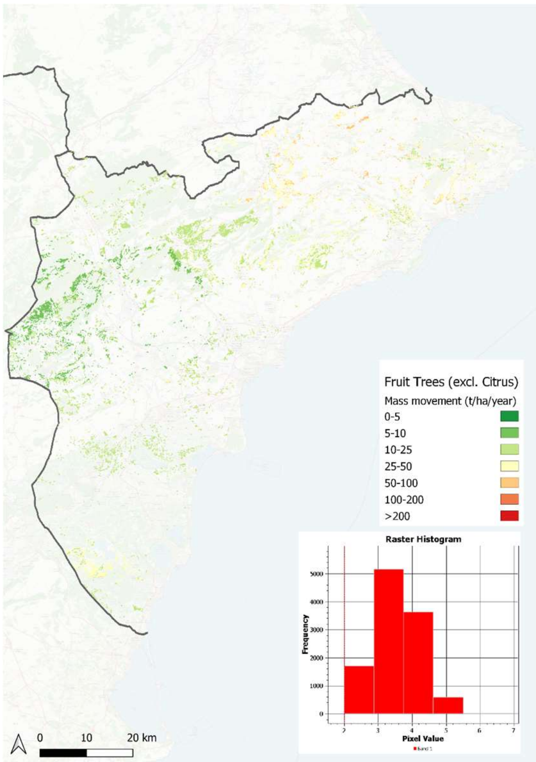


Figure 29 Erosion by mass movement in cultivations of fruit trees (excluding citrus fruit trees) (own elaboration).

Almost one third of the cultivation area (28.7%) is affected from laminar erosion with around 2 393 hectares being affected in very alarming way (category 6 and 7). The same accounts for the erosion by mass movement which almost the same amount (2 147 hectares; 1.3%) is affected there. Especially in the northern part of the province and in mountainous areas the erosion is high. The mayor area (5,7%) of the cultivation with 9 052 hectares is classified in category 3 with an erosion rate of 10-25 t/ha/year for laminar erosion. This is still a range which nature can recover, but 6,3% of the cultivation area is in high risk of serious erosion (categories 4-7) and action needs to be taken. This makes 10 043 hectares of highly erosive land surface.

	Coverage of cultivation in ha	Laminar Erosion	Surface of erosion category 6 and 7	Erosion by mass movement	Surface of highest erosion category 5
in ha	159080.7	45605.1	2393.25	45605.1	2147.1
in % of total cultivation	-	28.7	1.5	28.7	1.3

Table 3 Overview of erosion in fruit tree cultivations excluding citrus fruit trees (own elaboration).

The cultivation of fruit trees other than citrus fruit trees especially in the mountainous regions are not ecological sustainable in a way that high erosive rates are found. The agricultural practice must be improved to conserve the soil and probably actions to recover the soil for agricultural practices must be taken. As no information is available which fruit trees in detail are cultivated it is hard to identify whether there is a difference within the category regarding the erosion rates. As a category with exceptional high erosion rates further studies to distinguish the different rates for the different types of fruit trees are very recommended.

The ratio of organic farming practices in the cultivation of fruit trees (others than citrus trees) is with 6,8% the second highest class. This is particularly interesting in terms of erosion figures. Because the assumption that organic farming protects the soil cannot be confirmed so easily in this study. The highest erosion rates were found in the cultivation of fruit trees, which also have the highest proportion of organically farmed land.

This category has been very large, and it can be assumed that cultivation techniques vary greatly within this category. This is because there is a wide variety of farming practices, especially in the fruit tree sector. In addition, the growing regions of fruit trees are spread throughout the region. However, a high rate of erosion can be identified, especially in mountainous areas. This also speaks to the place of cultivation as an important factor about erosion. Whether the type of cultivation in this context is possibly even more decisive for the erosion rate than the agricultural cultivation practice can unfortunately not be conclusively clarified due to a lack of data.

Olives

The cultivation of olive trees has a long tradition in the Mediterranean and is mainly used for producing oil and some parts for consumption of the fruit itself. Olives are one of the main crops in the province of Alicante and the cultivation covers 31 991 hectares of the province in the year 2006 (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). In the data set of SIOSE 2005 83 784 hectares of the land are used for the cultivation of olive trees.

The main cultivation area is in the north and northwest of the province mainly inland. A large part of the trees was planted on slopes, since olive trees are very sensitive to waterlogging and need a good drainage system.

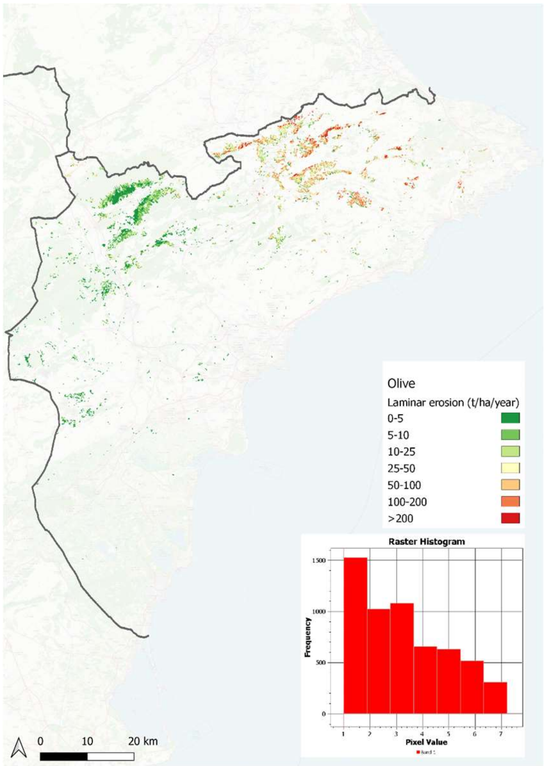


Figure 30 Laminar erosion in cultivations of olives (own elaboration).

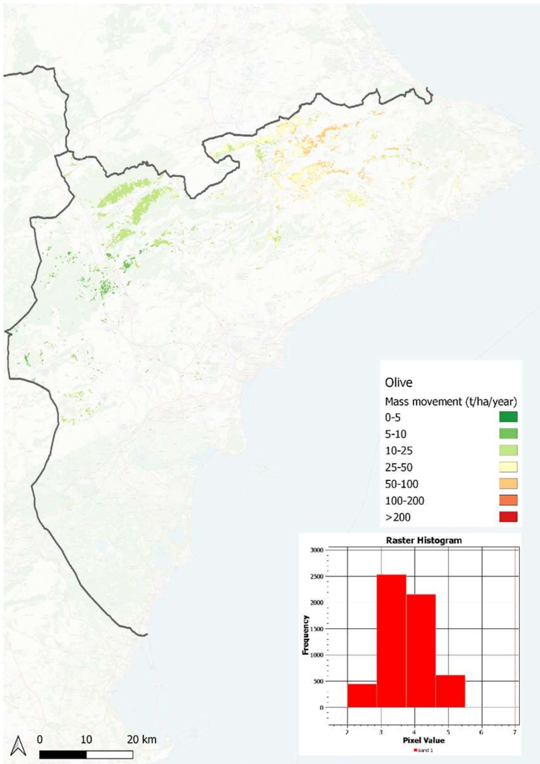


Figure 31 Erosion by mass movement in cultivations of olives (own elaboration).

More than a quarter of the land used for olive cultivation (26,8%; 22 451,6 hectares) is affected by laminar erosion, while 3 010 hectares are classified with category 6 or 7 and suffer from severe soil damage. The same applies to the erosion by mass movement with 3.5% of the cultivation area being in the highest class. Erosion rates are the highest of all cultivation types regarding the share of critical eroded surface from the cultivation area. In total surface area olive cultivation with high erosion rates are the highest of all crops and just behind pastures and meadows. Erosion is especially high in the northern cultivations as this are mountainous areas which favour water runoffs.

	Coverage of cultivation in ha	*Laminar Erosion*	*Surface of erosion category 6 and 7*	*Erosion by mass movement*	*Surface of highest erosion category 5*
in ha	83783.9	22451.6	3009.75	22451.6	2914.2
in % of total cultivation	-	26.8	3.6	26.8	3.5

Table 4 Overview of erosion in olive cultivations (own elaboration).

The cultivation practice seems to favour soil erosion and is in many cases not sustainable. Soil erosion is in many areas so high that a natural recovery is not possible. Olive trees usually are not plant with any vegetation cover to protect the soil so high erosion rates are not surprisingly.

In 2006, 1,134.8 hectares (3.55% of the total area of organic agriculture) was cultivated certified organic, and the trend is increasing. In 2019, it is already more than double with 2 551, hectares (8.87%) (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). Only relatively little acreage is cultivated with organic farming and the soil is not sufficiently protected. This is very alarming, as erosion rates are enormous and will cause great environmental damage even in the long term.

Although there is already an increase in organic farming for olive cultivation, it is still very little in terms of the large area. A shift to more sustainable practices is strongly needed.

About climate change, more heavy rainfalls are expected, which leads to severe erosion, especially in mountainous regions. In the case of olive cultivation, erosion rates are already very high. This means that due to the additional influence of climate change, a large damage can be assumed. Olive cultivation must urgently develop further, because it is currently not prepared for the influence of climate change.

Grapes

Grapes are used for consumption as fruit or to produce wine and are part of the agricultural landscape of the province since numbers are collected in the annual report (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). 22 986 hectares are used for the cultivation of grapes according to the annual report of Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica. In the SIOSE dataset 79 382 hectares are classified as grape cultivation area.

There are two areas used for the cultivation of grapes. One region is in the interior and another smaller area is in the northern coast. The wine and the grapes as such are protected by denomination of origin province of Alicante (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). Cultivation of grapes is very sensitive for temperature drops and requires much sunlight. Usually, grapes are cultivated in terraces to facilitate the required sunlight, this is very invasive as the soil has to be transformed to construct the wine terraces.

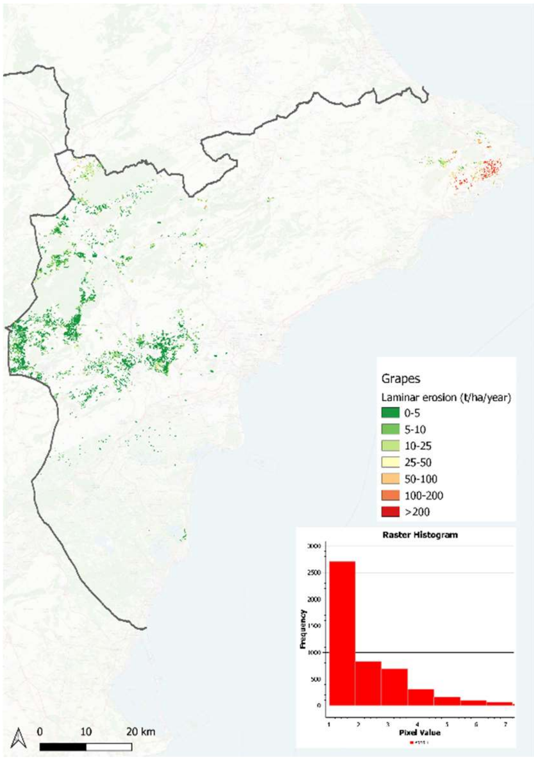


Figure 32 Laminar erosion in cultivations of grapes (own elaboration).

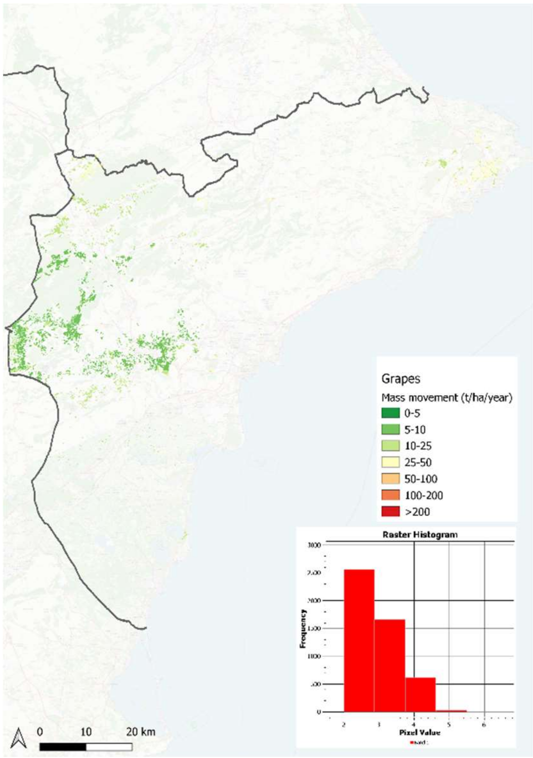


Figure 33 Erosion by mass movements in cultivations of grapes (own elaboration).

Of the 79 382 hectares of cultivation area 18 736 hectares are affected by laminar erosion (23.6%). Laminar erosion is in the middle field with 0.8% affected by high erosion rates (653 hectares) and only 100 hectares are affected by dramatic erosion by mass movement. The biggest share of 57% is classified with category 1 and another 31% with category 2 or 3.

	Coverage of cultivation in ha	Laminar Erosion	Surface of erosion category 6 and 7	Erosion by mass movement	Surface of highest erosion category 5
in ha	79381.9	18736.0	653.188	18736	100.0
in % of total cultivation	-	23.6	0.8	23.6	0.1

Table 5 Overview of erosion in grape cultivations (own elaboration).

The comparatively low rate of erosion by mass movement is surprising, since wine is often grown in terraces. But apparently the terraces are well constructed and i maintained, so that in our comparison group vine cultivation occupies the penultimate place and records very little erosion by mass movement. In the map it is evident that erosion is mainly concentrated in the region near the coast. Whether increased erosion occurs there due to weather conditions, geomorphology, or cultivation practices is not apparent from this data set.

The cultivation of grapes had the third highest share of cultivation area (5,8%) with organic agricultural practices after cereals (14,1%) and other fruit trees (6,79%). In 2019 it is in the middle field (11,65%) and only increased by 526 hectares compared to 2006. However, since erosion rates are not as severe, traditional farming methods appear to be largely protective of the soil even without certified organic farming. Only in the coastal region in the north of the province are erosion rates very high and more in-depth studies are recommended.

Regarding climate change, the erosion rate should be well monitored, because the increase of extreme events, as well as drought periods can lead to more severe erosion.

Meadows and pastures

Meadows and pastures are the mayor surface cover according to SIOSE with a total of 637 111 hectares. This is not surprising as in remote sensing large areas can be classified as meadows and pastures and steppes typical for the climatic zone are classified as such. The proportion of agriculturally used meadows and pastures is not recognizable. In the annual report of agriculture in the Valencian Community it is stated that in 2006 only 64 067 hectares are statistically recorded. However, this figure appears to be much too low.

This ground cover extends throughout the province. Both in the lowlands, as in the mountains, near the coast, as well as in the interior.

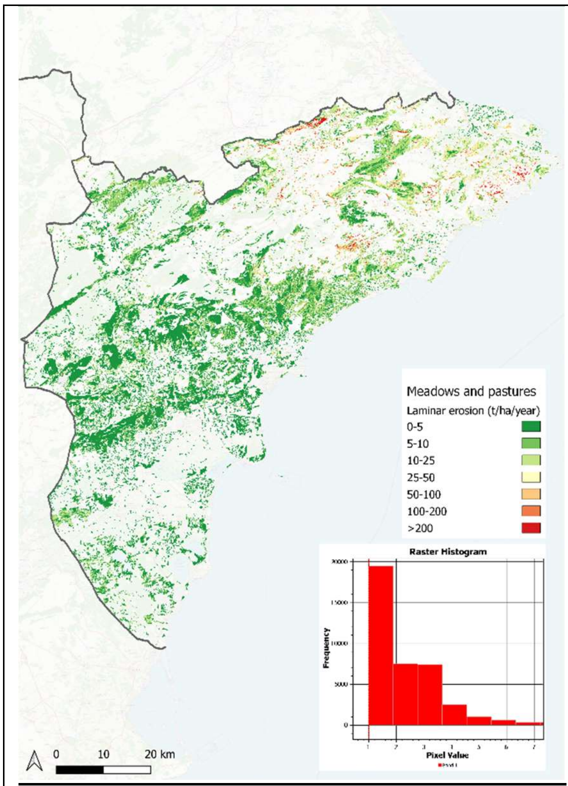


Figure 34 Laminar erosion in meadows and pastures (own elaboration).

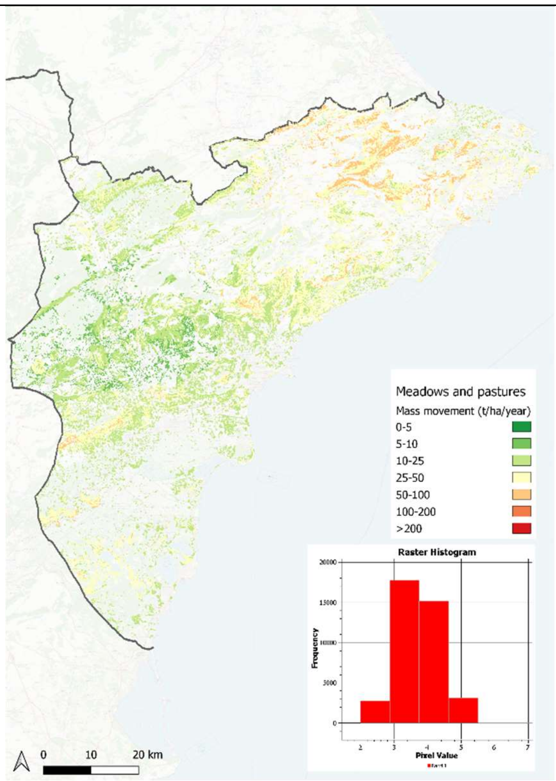


Figure 35 Erosion by mass movement in meadows and pastures (own elaboration).

Around 26% of the area is affected by laminar erosion, but only 0.6% of the total area is affected by laminar erosion of the category 6 or 7. Only 12% of the area affected by laminar erosion is classified in the alarming categories 5,6 and 7. While laminar erosion is very low, meadows and pastures have high rate of mass movement erosion (2.1%). Since it is also the largest land cover in terms of area, meadows and pastures are accordingly the most affected area for mass movement erosion. While laminar erosion is mainly concentrated in the north of the province usually in the mountainous areas, mass erosion is spread throughout the province with higher rates in the extreme north and south.

	Coverage of cultivation in ha	Laminar Erosion	Surface of erosion category 6 and 7	Erosion by mass movement	Surface of highest erosion category 5
in ha	637111.4	166072.5	3696.44	166072	13256.1
in % of total cultivation	-	26.1	0.6	26.1	2.1

Table 6 Overview of erosion in meadows and pastures (own elaboration).

The lack of information regarding the use of pastures and meadows makes it difficult to evaluate in terms of soil sustainability. Vegetative land cover is preferred over fallow land to minimize erosion (García-Orenes et al. 2012; Seitz et al. 2019; Teasdale et al. 2007) and this study also supports this finding. Meadow and pasture have a good protective function against laminar erosion. Erosion by mass movement is strikingly large. On the one hand, this may be due to the large area also present in mountains. But in general, the erosion by mass movement is raised in meadows and pastures even in the lowlands.

It would be interesting to see which meadows and pastures were planted for soil recovery and are part of agricultural use.

Regarding organic farming, no data is available for this land use.

The expected impacts of climate change with increased laminar erosion through meadows and pastures well be minimized. It is a good practice to let the soil recover. The effects of mass movement erosion and its interaction with climate change influences should be further investigated.

Fallow

Leaving land fallow is a common practice in conventional agriculture to allow the soil to recover and remineralize. However, various studies show the risk of high soil erosion from this practice (Gafforov et al. 2020; García-Orenes et al. 2012; Teasdale et al. 2007). In the province of Alicante, a total of 23 480 hectares are used in this way according to the SIOSE data set. In the annual report of the Valencian community 49 826 hectares are classified as fallow land. This is the only category where the annual report is showing a higher figure as the SIOSE data set. But especially the classification of fallow land is difficult using remote sensing.

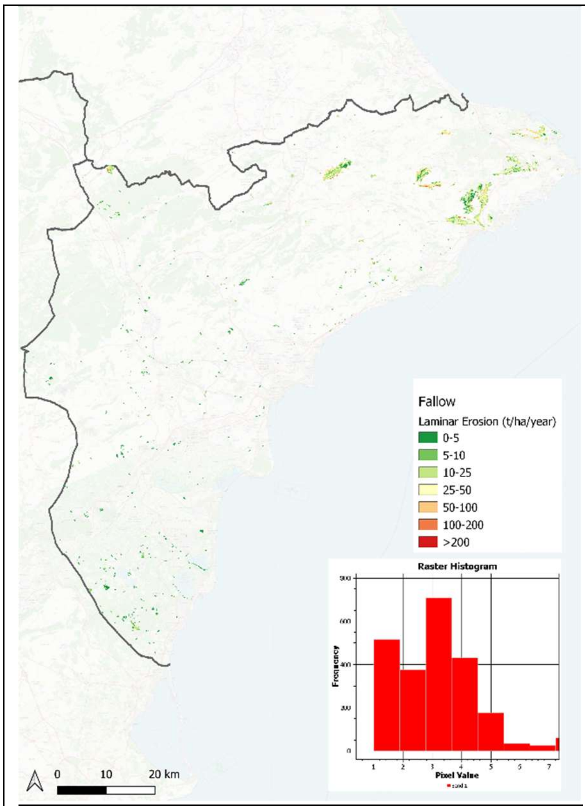


Figure 36 Laminar erosion in fallow land (own elaboration).

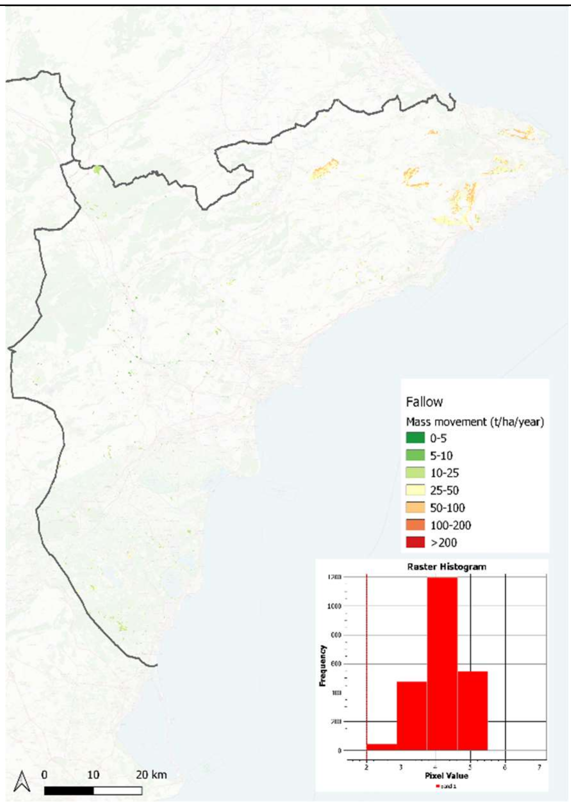


Figure 37 Erosion by mass movement in fallow land (own elaboration).

Fallow land has the highest share of land affected by laminar erosion with 38,6% (9 053 hectares). Only 0,7% show the highest erosion category 7, but on the other hand only 21% is classified with category 1. Great parts of the area are classified with class 4 or higher (2 682 hectares). Erosion by mass movement shows alarming rates with 8.8% of the total coverage is classified with the highest erosion category for mass movement.

The areas affected by laminar erosion are for great parts the same as the areas affected by erosion by mass movement and are located in the northern coastal area.

	Coverage of cultivation in ha	Laminar Erosion	Surface of erosion category 6 and 7	Erosion by mass movement	Surface of highest erosion category 5
in ha	23480.5	9053.1	163.5	9053.0625	2066.3
in % of total cultivation	-	38.6	0.7	38.6	8.8

Table 7 Overview of erosion in fallow land (own elaboration).

The two land uses of pasture, meadow, as well as fallow are two competing land uses in terms of soil restoration in agriculture. The comparison between these two practices in terms of erosion values is worthwhile to estimate the sustainability of the two practices (Figure 36 and 37). Meadows and pastures show a much greater percentage of soil with low erosion (category 1 and 2) than fallow land. Its open exposure makes it easy to erode soil layers, especially during wind and precipitation.

Even though category 7 is slightly higher for meadow and pasture than for fallow, this land use is still generally preferable for soil regeneration in respect to the effects of climate change.

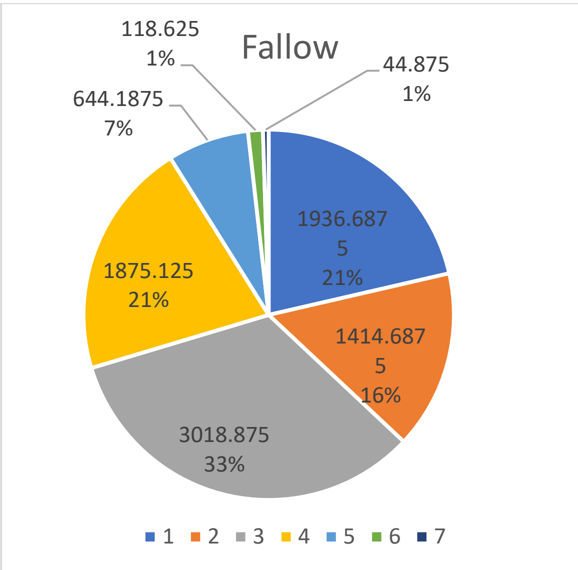


Figure 38 Share of different classifications of laminar erosion in fallow land (Source: own elaboration).

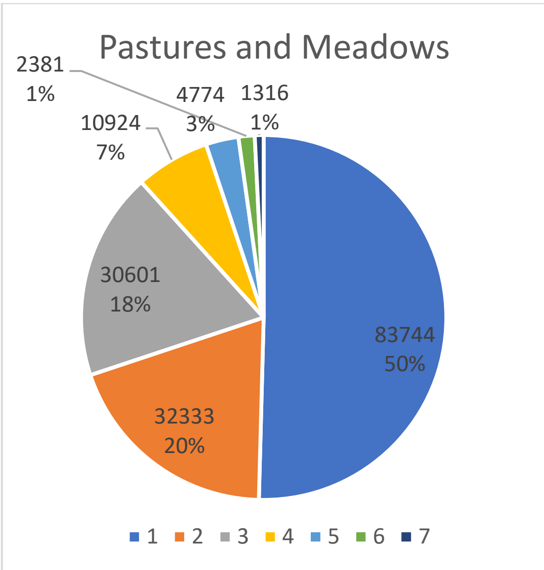


Figure 39 Share of different classifications of laminar erosion in Meadows and pastures (Source: own elaboration).

5. Discussion

A purely quantitative approach does not do justice to the question of which agricultural practice has the potential to feed the region in a sustainable and climate-friendly way. For this reason, the agricultural developments in the region must be analysed including more dimensions like social and economic and not only the environmental perspective.

There is already a very large body of research investigating the sustainability of organic and conventional agriculture. In this research, sustainability is considered in terms of the three perspectives of social, ecological, and economic, as it is also used in the SDGs. To help assess ecological sustainability, the planetary boundaries model is used.

The quality of the data is very high as many investigations support the findings. However, there is one limitation in the analysis of the data. The field research on different methods of agriculture and their sustainability was conducted in different regions. Due to different environmental influences, climatic conditions as well as agricultural techniques, a simple transfer of the results to the province of Alicante is not always possible. In addition, most of the studies on sustainability are rather large-scale. Much of the research focuses on the global impact of agriculture on climate change and vice versa. The results of this large-scale research are also only partly transferable to the province of Alicante. In the case of regional studies, similarities in terms of climate, environment or agricultural use are helpful, depending on the subject matter. But this is ~~is~~ an explanation of the differences between results of field studies and this research (for example regarding erosion rates in citrus fruit trees).

5.1 Ecological sustainability

The planetary boundaries help to decide if we are operating in safe area and therefore whether the systems can be classified sustainable. Agriculture has an impact on almost all these boundaries described in the model (see section 2.3).

On a global scale agriculture accounts for around 70% of freshwater withdrawal and as we already have seen in the previous section in the area of investigation it is a challenge as well (Campbell et al. 2017). Freshwater use is still in the safe operating space, but this varies greatly between regions. In Alicante freshwater exploitation is over the limits and exceeds the safe operating space (García-Orenes et al. 2012; Cazcarro et al. 2015). Right now Spain's strategy is to improve the irrigation infrastructure to limit water loss (Khadra and Sagardoy 2019) but in general this is not enough regarding the steep increase of water for irrigation needed in the agricultural practices which they are using. Organic agriculture is an efficient way for water management as it has more capacity to hold water in the soil and reduces water loss (Gomiero et al. 2011) and prevent desertification.

The connection between deforestation or land use change with agriculture is easy to recognize. Agricultural land is one of the most extensive form of land use at global scale (Worldbank 2020). There is a direct link on how the transformation of land for the use of agriculture affects our environment on many levels. Linked with the land use change, monoculture, and the use of pesticides many species got distinct. A study from Benton et al. (2021) found out that agriculture is the main risk for 86% of the plant and animal species known to be at risk of extinction. No other anthropologic activity shows such a dramatic impact on biodiversity like agriculture (Rockström et al. 2009), but on the other hand is organic agriculture a possible way to promote and preserve biodiversity, if yield maximisation is not the only focus (Siegrist et al. 1998). The steep incline in greenhouse cultivation in the province Alicante has a negative impact on biodiversity and are rather a way backwards. Especially the often used Southern-type greenhouses have a negative impact on biodiversity and do not the offer the positive impact modern greenhouses can have. At the same time organic agriculture presents only a small share of the used agricultural practices though its positive impacts on biodiversity are shown (Ecologistas en Acción 2019; Muller 2016; Reganold et al. 1987).

Regarding climate change agriculture has a great role to play as up to one third of all anthropogenic greenhouse gas emissions come directly from agriculture (Ricart et al. 2019; Masson-Delmotte et al. 2019). Ocean acidification is indirectly linked to agriculture as its cause is the absorption of CO2 in the air from the ocean. But Alicante as a coastal province with high level of soil erosion contributes to great levels in the pollution of the oceans with fertilizers and pesticides which are washed with the eroded soil in the Mediterranean Sea. In this study agricultural practices could be clearly identified as an essential factor influencing soil erosion rates and higher erosion rates due to climate change are expected (Gafforov et al. 2020). The province Alicante shows many surfaces with alarming high erosion rates with the cultivation or soil restoring strategy as important drivers. Some crop types or agricultural practices seem to have positive impact on soil conservation and can offer a solution to adapt to climate change, while other practices and crop types increase soil erosion. The cultivation of citrus trees and the increase of meadows and pastures in the province are good news for limiting soil erosion, while especially fallow land and olive trees have an alarming negative impact.

But agriculture offers the opportunity to act as a carbon sink and to mitigate climate change (Masson-Delmotte et al. 2019). The service of the ecosystem is only possible with an environmentally sustainable land management and reduction of fallow land and erosion rates. In the province Alicante the use of fallow land is still very common (38 889 hectares in 2019), but is showing a slight negative trend over the time (Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019). “Micro-irrigation, restoring degraded lands using drought resilient ecologically appropriate plans, agroforestry, and other agroecological and ecosystem based adaptation practices” (Masson-Delmotte et al. 2019,

p. 22) are promising to be capable to mitigate climate change and increase the potential of agriculture to act as carbon sink. So, the positive trend in the use of organic agriculture and the decline of fallow land is a positive development in the province.

Another big negative impact of agriculture is the nitrogen cycle, which has greatly been transformed by agriculture. The nitrogen cycle has been transformed by agriculture through its intense use as fertilizer leading to enormous damage for ecosystems (Rockström et al. 2009; Campbell et al. 2017). The same applies for the phosphorus cycle, though it is still in a safe operating area, phosphor used as fertilizer is a serious intervention in the natural phosphorus cycle (Campbell et al. 2017). A total of 96% of mined phosphor is used as fertilizer and therefore added to the natural cycle (Carpenter and Bennett 2011). With the high level of soil erosion, which washes out nutrition and an intensification of the agriculture in the province the application of fertilizers is more and more needed. This brings more harmful nitrogen into the environment.

Especially the pausing of agricultural use by fallow land or meadows and pastures to remineralize the soil has a great impact on sustainability. Especially fallow land shows very high erosion rates and “cover crops are required to protect the soil from erosion” (Siegrist et al. 1998, p. 262). However, the positive trend of surface cover of meadows and pastures in the province is a step in the right direction (Gomiero et al. 2011). During periods of cultivation organic cultivation practices reduce soil erosion rates and should be considered in the regions of high erosion rates in the province (Seitz et al. 2019).

5.2 Social sustainability

In the assessment of agriculture, the social aspect of sustainability has been assessed less than the economic or environmental sustainability (Shreck et al. 2006). This is mainly because social sustainability is more difficult to be measured using statistics. Another contributing fact is that social and natural sciences have historically seen as two very distinct areas of research and were not supposed to be combined. Though this view has been revised during the time the combination of social and natural science in research is still rare (Becker and Jahn 1999). The aspects to be examined about social sustainability are highly controversial and subject to interpretation (Boström 2012). Depending on political or social interests, different parameters are added or omitted in order to create a desired picture (Eizenberg and Jabareen 2017). This can also happen with the dimensions of economic and ecological sustainability, but the aspect of social sustainability is still very vaguely used in the discourse.

To assess the social sustainability two important stakeholders~~,~~ must be included: **consumers** and **producers**.

From the perspective of consumers, sustainable agriculture is one that provides society with a reliable and healthy diet without compromising health of it or the health of future generations. The use of genetically modified foods, which have not yet been sufficiently researched, or pesticide residues on food that are hazardous to health contradict the understanding of a socially sustainable agriculture (Janker et al. 2019).

In addition, consumers have the right to know under which conditions their food was produced and to what extent it has a negative impact on the environment. This is because the large amount of water used to grow water-intensive crops is in direct competition with water use in other sectors, such as tourism or domestic use. By increasing a country's water footprint, one must also expect increased water costs, as well as possible water shortages (Cazcarro et al. 2015).

Agriculture also has a direct impact on global warming (Moutahir 2016; Masson-Delmotte et al. 2019; Crane-Droesch and Marshall 2019), with unsustainable practices endangering the environment and thus society's habitat. Desertification, heavy rainfall events and soil erosion have a direct impact of the consumers and population of the region. As some regions will not be suitable for living or under higher risk of natural disaster (Olcina et al. 2016).

From the perspective of the producers, as well as the workers involved in the sector, social sustainability means the possibility of creating a fair livelihood for people. This includes educational opportunities, security and gender equality (Torres et al. 2016). In the research done by Torres et al.(2016) in the close by region Almeria the impact of organic agriculture on social sustainability has been assessed during a ten years period. It resulted that organic agriculture created a rise in the employment and in this way reducing unemployment. As organic agriculture is more labour intensive this had a positive impact on the job market. But

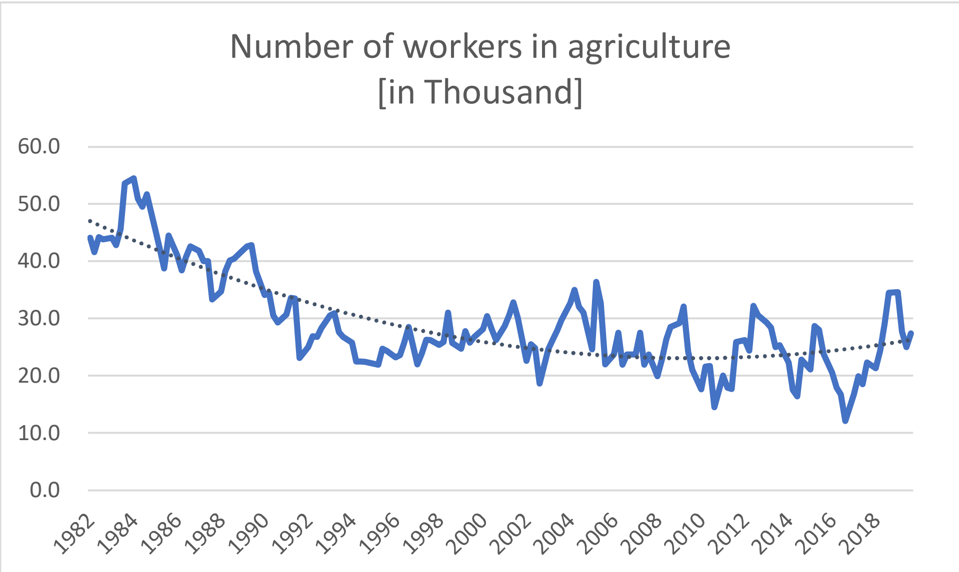


Figure 40 Number of workers in the agricultural sector between 1982 and 2019 (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

looking on the educational background of the people employed and the development of the education there was no change seen. The new employees had a little educational background and organic agriculture could not improve the education level of the workers in this sector.

In the province of Alicante, it is also possible to see an increase in the number of people employed in agriculture from 2008, although the area used for agriculture has constantly decreased (see Figure 40 and 22). Around 2008 the surface of organic agricultural land use started to increase, and this can be related to the employment.

In terms of social sustainability, it is a positive development that more people can find work and thus earn a living. One point of improvement, however, would be the level of education in connection with the employees. It would be a good development if the level of education of the people would also improve. With regard to gender equality, Torres et. al. (2016) was also unable to identify any improvements in his study. This would still be a desirable aspect.

Another aspect regarding the social sustainability is that a careful agriculture does not destroy its own livelihood by destroying the soil. Since we do not have comparative data regarding erosion, it is not possible to make a statement about the development, but some fields are affected by dramatic erosion rates and also in terms of social sustainability remedial action should be taken there, because otherwise the livelihood of the farms can be destroyed. The high soil erosion results in fertility loss and therefore less productivity of the land, which has negative impact on the social sustainability but as well on the economic sustainability (Gafforov et al. 2020), while organic agriculture has the benefit to restore the soil organic matter and fertility of the soil (Gomiero et al. 2011).

5.3 Economic sustainability

Economic sustainability in agriculture means an economic system in the sense of profitability and consistency. Profitability in the sense that the production costs do not exceed the sales values and thus mean a loss or even too little profit. Consistency means that profits are stable and predictable. Because only in this way can an agricultural business operate successfully.

The impact of climate change on the economics of agriculture is clear. The increase in extreme weather events has also clearly increased the damage they cause to crops (see Figure 41). With the further projected course of climate change, a further increase in these damages is to be expected. Not only due to the increased extreme weather events, a higher economic damage is to be expected, but also by the larger harvest quantity per hectare, which constantly happens due to the intensification of the agriculture. A damage of the same spatial extent results in more economic damage than it was still the case at the beginning of the records.

Organic agriculture appears to have higher resilience to extreme events (Gomiero et al. 2011), although we could not clearly investigate this in this study. This means the positive trend in

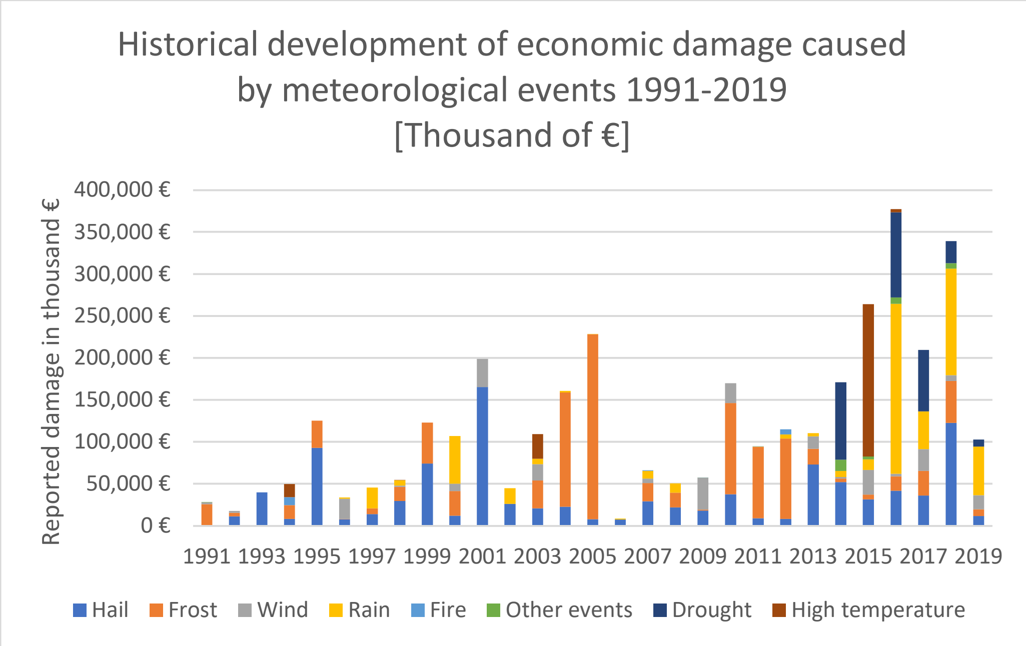


Figure 41 Historical development of economic damage caused by meteorological events in the valencian community (Source: Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica 1998-2019, own elaboration).

organic agriculture in the province of Alicante is a good way to reduce economic risk in the context of climate change. However, it is not only the question of whether to grow organically or conventionally, but also the farming activities in detail, the crop as well as the region of cultivation that have a significant impact on the economic sustainability of agriculture.

The conversion from conservative agriculture to organic agriculture is associated with costs, educational work and also crop losses in the initial phase (Gomiero 2018). Especially the transition is a financial challenge, as the soil most likely has to be restored first, new investments have to be made and also the harvest is lower at first. In this phase, the products may often not yet be sold with the certificate, because important quality characteristics (e.g. with regard to the pesticide load of the soil) are not yet given. The study from Masson-Delmotte et al. (2019) show that organic farming becomes profitable within three to ten years. This is a challenge for smaller farms in particular.

The organic food business is a growing one. In 2018, 25% of all sales in the food industry in Spain were already from organic food and this positive trend has been prevailing for many years (Comité de Agricultura Ecológica de la Comunitat Valenciana 2020). From 2016 to 2020, the share increased by 124.4% (Comité de Agricultura Ecológica de la Comunitat Valenciana 2020). Half of the organic food produced is exported to other EU countries and 16% is distributed directly in the Valencia community.

While the conversion from conventional to organic agriculture is associated with high costs, the cultivation of organic fruit and vegetables is profitable if the conversion is successful. Profitability can be expected after five years on average (Bellon and Penvern 2014). As with a large number of new methods, of course, widespread use and the expansion of the corresponding infrastructure for the cultivation and marketing of organic foods is helpful in reducing costs (Gomiero 2018). A larger market share leads probably to better economic conditions.

In the social sustainability part, it has already been mentioned that organic farming is more labour intensive, and accordingly more jobs are created. This is, of course, bad from the perspective of economic sustainability, because it means that production costs continue to rise. If you look at the profitability for a short period of time it leads to poor results. However, the benefit in organic agriculture lies in its ability to provide long-term solutions. Because of the careful use of the soil, the use of fertilizers and pesticides is constantly reduced and therefore this cost is less. The same is true for soil restoration and the greater resilience to environmental impacts leads to less crop loss due to extreme weather events (Ecologistas en Acción 2019).

The introduction of certificates for organic farming has made it possible to identify the products and thus also to pass on the additional costs to the customer in an understandable way. The certification allows on the one hand a quality feature, as well as an increased transparency for the customer, but at the same time is a motivation for farms to invest in sustainable practices (Masson-Delmotte et al. 2019).

6. Conclusion

In this study it has become clear that not only the agricultural practice whether organic or conventional have an impact on the sustainability and the capabilities to adapt and mitigate climate change, but also the crop species, the region where it was grown and the agricultural activities in detail.

In order to answer the research question what are the expected and already observed impacts of climate change on agriculture and what agricultural practices are suitable for a climate-friendly agriculture in the province of Alicante, it is also important to look at the different scales there. Organic agriculture offers the potential of sustainable and climate-friendly agriculture, but there are also areas that achieve good results with conventional agricultural practices. The strong trend regarding water-intensive fruits is alarming, as water scarcity already exists and can be expected to increase in the future. A struggle of resources is already foreseeable. The motivation to modernize the irrigation system has resulted in an increase in the cultivation of plants with high water needs (see section 4.2).

The processes of soil erosion are also directly related to climate change and are strikingly high in olive cultivation, fruit trees, as well as grape cultivation. These are all important crops of the province and, in this context, of economic, environmental, and social importance. Special attention should be paid to the practice of soil recovery in fallow land. Because this study was also able to clearly show that fallow land poses a great risk to the soil and is not a sustainable practice in most cases. It is more appropriate to cultivate grass or simple vegetative cover to protect the soil from desertification and erosion during the period of soil recovery.

The research question could only be answered to a very limited extent due to the availability of data. Since very little data are available, especially with regard to agricultural practice, a few aspects remain unanswered. Also with regard to the development and the positive or negative developments after the change of an influencing factor could only be examined to a very limited extent, since only very little data is available over a longer period of time. With regard to erosion in particular, it would have been exciting to examine the area at at least two different points in time and to compare the results. On this occasion, a repetition of this study is recommended as soon as new data on soil erosion are available.

Climate change is already having an impact on agriculture, and those impacts are very likely to be stronger over time. The climate is characterized by extreme weather events, such as heavy rain or dry periods, which on the one hand require a good water collection and storage system. But on the other hand, we have to start directly with the plants and the soil. There we need resilient plants and a soil that has high storage capacities for water and minerals and is protected against erosion.

There is clear evidence that organic agriculture offers opportunities for climate adaptation and mitigation (Crane-Droesch and Marshall 2019; Masson-Delmotte et al. 2019; van Knooten 2020), but these are not so easily generalized to all regions. For the province of Alicante, this means that intensive research into the opportunities for climate-smart agriculture in the province are strongly recommended. Although the province of Alicante offers a challenge in the development of general recommendations due to its diverse climate, it also offers the opportunity to explore a variety of different climates in terms of their constraints and opportunities for climate-smart agriculture, and in this sense to help other countries with similar climatic conditions.

The bottom line is that climate change is a global challenge that must be reflected in local action. Agriculture has a very large share in anthropogenic climate change, but at the same time offers opportunities for adaptation and mitigation. The province of Alicante seems to have already discovered good strategies in some regions, which should be identified and disseminated. The change from bad already naturalized agricultural practices to new ones always costs financial resources, education and persuasion of farmers, politicians, and society to change the status-quo. However, in the context of an economically, ecologically and socially sustainable agriculture, it is the only right way. While the transition from conservative agriculture to organic agriculture involves a lot of cost and effort, there are also a few simple practices that can already have a big impact such as avoiding fallow land, minimizing tillage, and many more.

However, in order to be able to identify good strategies and not to base this assessment purely on subjective criteria, it is important to collect as much statistical data as possible describing the sustainable development of agriculture. It is not enough to collect data only once, but these data should be collected at regular intervals so that trends can also be identified. Only in this way is it possible to distinguish good strategies from bad ones.

An important finding of this study is that the scale used can have a significant impact on the results. For example, some agricultural practices may be considered highly sustainable at the global level but produce very different results at the regional or local level. An example is the cultivation of citrus fruits, which have been classified in many studies as very damaging to the soil, but in the province of Alicante it could not be confirmed. Nevertheless, there are local differences within the province regarding the harmfulness or not of the cultivation of citrus fruits. Agriculture is influenced by many different aspects and for this very reason general conclusions are very difficult to draw and always possible only from a limited perspective.

With regard to economic, ecological and social sustainability, the aspect of the scale is also important, in this context the time (Gomiero 2018). Looking at the short term in particular, the switch from conservative to organic sustainability is difficult and involves a lot of effort and expense. However, in terms of our responsibility to future generations, it is the only right way to transform agriculture. However, what exactly sustainable agriculture means in individual cases has to be found out through further research, especially at regional and local level.

A transition from one day to the next will not be so easy, because on the one hand there is still a lack of research, but on the other hand there is also a lack of funding and education in this area. Agriculture concerns us all because it forms our livelihood and that of future generations. The particular challenge is that we have a steady increase in the world population and, in this context, the need for food is also increasing. Furthermore, climate change leads to more difficult conditions in agriculture. For this reason, we are forced to rethink. Climate change will force us to change and now it is particularly important to use these changes in a positive way.

Organic agriculture can only develop its full potential if it is implemented on a large scale. This requires many farms that opt for organic farming. So far only a small part of the agricultural area in the province has been used organically. While the trend is positive, there should be a faster development in relation to the quick development of climate change. The conversion of agriculture takes time, but the question is, how much time do we have left?

Publication bibliography

Aemet (2018): Mapas climaticos Espana. 1981-2021. With assistance of Aemet. Aemet. Madrid.

Aemet (2021): Climate projections for the XXI Century. Aemet. Available online at http://www.aemet.es/en/serviciosclimaticos/cambio_climat/result_graficos?opc4=0&w=0&opc1=03&opc2=Tx&opc3=Anual&opc6=0&img=1, checked on 4/26/2021.

Antón, A.; Castells, F.; Montero, J. I.; Huijbregts, M. (2004): Comparison of toxicological impacts of integrated and chemical pest management in Mediterranean greenhouses. In *Chemosphere* 54 (8), pp. 1225–1235. DOI: 10.1016/j.chemosphere.2003.10.018.

Becker, Egon; Jahn, Thomas (1999): Sustainability and the social sciences. A cross-disciplinary approach to integrating environmental considerations into theoretical reorientation / edited by Egon Becker and Thomas Jahn. London: Zed Books.

Belda, Ferdando; Meliá, Joaguin (2000): Relationships between climatic parameters and forest vegetation: application to burned area in Alicante (Spain). In *Forest Ecology and Management* 135 (1-3), pp. 195–204. DOI: 10.1016/S0378-1127(00)00310-8.

Bellon, Stéphane; Penvern, Servane (Eds.) (2014): Organic Farming, Prototype for Sustainable Agricultures. Prototype for Sustainable Agricultures. Dordrecht: Springer Netherlands. Available online at http://dx.doi.org/10.1007/978-94-007-7927-3.

Bellot, Juan; Bonet, Andreu; Peña, Juan; Sánchez, Juan Rafael (2007): Human impacts on land cover and water balances in a coastal Mediterranean county. In *Environmental Management* 39 (3), pp. 412–422. DOI: 10.1007/s00267-005-0317-9.

Benton, T.; Bieg, C.; Harwatt, H. (2021): Food system impacts on biodiversity loss. Three levers for food system transformation in support of nature. The Royal Institute of International Affairs. London. Available online at https://www.chathamhouse.org/2021/02/food-system-impacts-biodiversity-loss/02-how-todays-food-system-drives-biodiversity-loss, checked on 4/29/2021.

Berbel, J.; Expósito, A.; Mateos, L. (2018): The Importance of the Groundwater Governance in the Global Change Context: A Proposal for a Mediterranean Aquifer (Llanos de la Puebla, Spain). In Maria Luisa Calvache, Carlos Duque, David Pulido-Velazquez (Eds.): Groundwater and global change in the western Mediterranean area. Cham: Springer (Environmental Earth Sciences), pp. 35–42.

Bergstrand, Karl-Johan I. (2010): Approaches for mitigating the environmental impact of greenhouse horticulture. Alnarp: Department of Horticulture, Swedish University of Agricultural Sciences (Acta Universitatis agriculturae Sueciae, 2010:93).

Boström, Magnus (2012): A missing pillar? Challenges in theorizing and practicing social sustainability: introduction to the special issue. In *Sustainability: Science, Practice and Policy* 8 (1), pp. 3–14. DOI: 10.1080/15487733.2012.11908080.

Calvache, Maria Luisa; Duque, Carlos; Pulido-Velazquez, David (Eds.) (2018): Groundwater and global change in the western Mediterranean area. Cham: Springer (Environmental Earth Sciences).

Campbell, Bruce M.; Beare, Douglas J.; Bennett, Elena M.; Hall-Spencer, Jason M.; Ingram, John S. I.; Jaramillo, Fernando et al. (2017): Agriculture production as a major driver of the Earth system exceeding planetary boundaries. In *E&S* 22 (4). DOI: 10.5751/ES-09595-220408.

Carpenter, Stephen R.; Bennett, Elena M. (2011): Reconsideration of the planetary boundary for phosphorus. In *Environ. Res. Lett.* 6 (1), p. 14009. DOI: 10.1088/1748-9326/6/1/014009.

Casas, J. Jesús; Bonachela, Santiago; Moyano, Francisco J.; Fenoy, Encarnación; Hernández, Joaquín (2014): Agricultural Practices in the Mediterranean. In Victor Preedy (Ed.): The Mediterranean diet. 1st edition. Boston MA: Elsevier, pp. 23–36.

Castilla, N. (1994): Greenhouses in the mediterranean area. Technological level and strategic management. In *Acta Hortic.* (361), pp. 44–56. DOI: 10.17660/ActaHortic.1994.361.3.

Castro, Antonio J.; López-Rodríguez, María D.; Giagnocavo, Cynthia; Gimenez, Miguel; Céspedes, Leticia; La Calle, Abel et al. (2019): Six Collective Challenges for Sustainability of Almería Greenhouse Horticulture. In *International journal of environmental research and public health* 16 (21). DOI: 10.3390/ijerph16214097.

Cazcarro, Ignacio; Duarte, Rosa; Martín-Retortillo, Miguel; Pinilla, Vicente; Serrano, Ana (2015): How Sustainable is the Increase in the Water Footprint of the Spanish Agricultural Sector? A Provincial Analysis between 1955 and 2005–2010. In *Sustainability* 7 (5), pp. 5094–5119. DOI: 10.3390/su7055094.

Comité de Agricultura Ecológica de la Comunitat Valenciana (2020): Informe del sector ecologico. Available online at https://www.caecv.com/wp-content/uploads/2021/05/Informe.pdf, checked on 6/7/2021.

Comité de d’Agricultura Ecològica de la Comunitat Valenciana (2020): Statistics. CAECV, checked on 4/27/2021.

Conselleria de Agricultura, Desarrollo Rural, Emergencia Climática y Transición Ecológica (1998-2019): Informe del Sector Agrario Valenciano. 1998-2019. With assistance of

Comunidad Valenciana. Valencia. Available online at http://agroambient.gva.es/es/informes-del-sector-agrario-valenciano, checked on 4/21/2021.

Crane-Droesch, A.; Marshall, E. (2019): Climate Change and Agricultureal Risk Management Into the 21st Century. United States Department of Agriculture. USA.

Dirección General para la Biodiversidad (2006): Inventario nacional erosión suelos. 2002-2012. Alicante Comunidad Valenciana. With assistance of Eduardo del Palacio Fernández-Montes, Leopoldo Rojo Serrano, María Torres-Quevedo García de Quesada, José Hernández Álvarez. Ministerio de Medio Ambiente. Alicante. Available online at https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-nacional-erosion-suelos/default.aspx, checked on 4/26/2021.

Ecologistas en Acción (2019): Agroecología para enfriar el planeta. Edited by Ecologistas en Acción.

Eizenberg, Efrat; Jabareen, Yosef (2017): Social Sustainability: A New Conceptual Framework. In *Sustainability* 9 (1), p. 68. DOI: 10.3390/su9010068.

EUROSTAT (2020): Database. EU. Available online at https://ec.europa.eu/eurostat/data/database, checked on 5/10/2021.

Food and Agriculture Organization of the United Nations (2020): Database. FAO. Available online at http://www.fao.org/statistics/en/, checked on 3/15/2021.

Gafforov, Khusen Sh.; Bao, Anming; Rakhimov, Shavkat; Liu, Tie; Abdullaev, Farkhod; Jiang, Liangliang et al. (2020): The Assessment of Climate Change on Rainfall-Runoff Erosivity in the Chirchik–Akhangaran Basin, Uzbekistan. In *Sustainability* 12 (8), p. 3369. DOI: 10.3390/su12083369.

García-Orenes, F.; Roldán, A.; Mataix-Solera, J.; Cerdà, A.; Campoy, M.; Arcenegui, V.; Caravaca, F. (2012): Soil structural stability and erosion rates influenced by agricultural management practices in a semi-arid Mediterranean agro-ecosystem. In *Soil Use Manage* 28 (4), pp. 571–579. DOI: 10.1111/j.1475-2743.2012.00451.x.

Gomiero, Tiziano (2018): Agriculture and degrowth. State of the art and assessment of organic and biotech-based agriculture from a degrowth perspective. In *Journal of Cleaner Production* 197, pp. 1823–1839. DOI: 10.1016/j.jclepro.2017.03.237.

Gomiero, Tiziano; Pimentel, David; Paoletti, Maurizio G. (2011): Environmental Impact of Different Agricultural Management Practices. Conventional vs. Organic Agriculture. In *Critical Reviews in Plant Sciences* 30 (1-2), pp. 95–124. DOI: 10.1080/07352689.2011.554355.

Holzapfel, E. A.; Mariño, M. A. (2008): Irrigation in Agriculture. In Sven Erik Jørgensen, Brian D. Fath (Eds.): Encyclopedia of ecology. 1st edition. Amsterdam: Elsevier, pp. 2033–2039.

Available online at https://www.sciencedirect.com/science/article/pii/B9780080454054006285.

Hulme, Mike; Dessai, Suraje; Lorenzoni, Irene; Nelson, Donald R. (2009): Unstable climates: Exploring the statistical and social constructions of 'normal' climate. In *Geoforum* 40 (2), pp. 197–206. DOI: 10.1016/j.geoforum.2008.09.010.

INE (2021): Banco de datos. With assistance of INE. INE. Madrid. Available online at https://www.ine.es/, checked on 4/19/2021.

Infante Amate, Juan; González de Molina, Manuel (2013): 'Sustainable de-growth' in agriculture and food: an agro-ecological perspective on Spain's agri-food system (year 2000). In *Journal of Cleaner Production* 38, pp. 27–35. DOI: 10.1016/j.jclepro.2011.03.018.

Instituto Geográfico Nacional (2021): Geodesia. Available online at https://www.ign.es/web/ign/portal/gds-area-geodesia, checked on 4/21/2021.

International Federation of Organic Agriculture (2020): The four principles of organic agriculture. IFOA. Bonn. Available online at https://www.ifoam.bio/principles-organic-agriculture-brochure, checked on 4/26/2021.

Janker, Judith; Mann, Stefan; Rist, Stephan (2019): Social sustainability in agriculture – A system-based framework. In *Journal of Rural Studies* 65, pp. 32–42. DOI: 10.1016/j.jrurstud.2018.12.010.

Khadra, Roula; Sagardoy, Juan Antonio (2019): Irrigation Governance Challenges in the Mediterranean Region. Learning from Experiences and Promoting Sustainable Performance. Available online at https://doi.org/10.1007/978-3-030-13554-6.

Marcelis, L.F.M.; van den Boogaard, R.; Meinen, E. (Eds.) (2000): Control of crop growth and nutrient supply by the combined use of crop models and plant sensors. Horticulture and Post-harvest Processing. Int. Conf. Modelling and Control in Agriculture. IFAC.

Masson-Delmotte, V.; Pörtner, H.; Zhai, P. (2019): Climate Change and Land. IPCC Special Report on climate change, desertification, landdegradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for Policymakers. IPCC.

Meseguer-Ruiz, Oliver; Olcina Cantos, Jorge; Sarricolea, Pablo; Martín-Vide, Javier (2017): The temporal fractality of precipitation in mainland Spain and the Balearic Islands and its relation to other precipitation variability indices. In *Int. J. Climatol.* 37 (2), pp. 849–860. DOI: 10.1002/joc.4744.

Ministerio de Agricultura, Pesca y Alimentación (2019): Encuesta sobre Superficies y Rendimientos de Cultivos. Available online at https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/esyrce/, checked on 6/7/2021.

Miró, J. J.; Estrela, Mª.J.; Caselles, V.; Olcina Cantos, J. (2016): Fine-scale estimations of bioclimatic change in the Valencia region, Spain. In *Atmospheric Research* (1809), pp. 150–164.

Mitri, George; Nasrallah, Georgy; Gebrael, Karen; Bou Nassar, Maria; Abou Dagher, Manale; Nader, Manal et al. (2019): Assessing land degradation and identifying potential sustainable land management practices at the subnational level in Lebanon. In *Environ Monit Assess* 191 (9), p. 56. DOI: 10.1007/s10661-019-7739-y.

Morote Seguido, Álvaro Francisco (2020): Experiencia didáctica en postgrado sobre la interpretación de los riesgos naturales y el cambio climático. Ejemplos de estudios de caso en la provincia de Alicante (España). In *CGUV* (103), p. 47. DOI: 10.7203/CGUV.103.16015.

Moutahir, Hassane (2016): Likely effects of climate change on water resources and vegetation growth period in the province of Alicante, southeastern Spain. Available online at https://rua.ua.es/dspace/bitstream/10045/70649/1/tesis_hassane_moutahir.pdf, checked on 11/1/2021.

Muller, A. et al. (2016): Organic Farming, Climate Change Mitigation and Beyond. Reducing the environmental impacts of eu agriculture. Available online at http://www.ifoam-eu.org/sites/default/files/ifoameu_advocacy_climate_change_report_2016.pdf.

Neal, Larry; García-Iglesias, María Concepción (2013): The economy of Spain in the euro-zone before and after the crisis of 2008. In *The Quarterly Review of Economics and Finance* 53 (4), pp. 336–344. DOI: 10.1016/j.qref.2013.01.002.

Olcina, Jorge (2017): Incremento de episodios de inundación por lluvias de intensidad horaria en el sector central del litoral mediterráneo español: análisis de tendencias en Alicante. In *1137-9669*. Available online at http://rua.ua.es/dspace/handle/10045/73413.

Olcina, Jorge; Sauri, David; Hernández, Maria; Ribas, Anna (2016): Flood policy in Spain: a review for the period 1983-2013. In *Disaster Prevention and Management* 25 (1), pp. 41–58. DOI: 10.1108/DPM-05-2015-0108.

Olcina Cantos, Jorge; Baños Castiñeira, Carlos J.; Rico Amorós, Antonio M. (2016): Medidas de adaptación al riesgo de sequía en el sector hotelero de Benidorm (Alicante, España). In *Rev. geogr. Norte Gd.* (65), pp. 129–153. DOI: 10.4067/S0718-34022016000300007.

Olcina Cantos, Jorge; Moltó Mantero, Enrique (D.L. 2019): Climas y tiempos del País Valenciano. Sant Vicent del Raspeig: Publicacions de la Universitat d'Alacant (L'Ordit, 19).

Pardossi, Alberto; Tognoni, Franco; Incrocci, Luca (2004): Mediterranean greenhouse technology. Available online at https://edepot.wur.nl/414569, checked on 5/10/2021.

Piske, Jana (2019): SDG 2 “Zero Hunger by 2030” in Southern Asia. A framework to end hunger? Bachelor. Albert-Ludwigs University, Freiburg im Breisgau.

Planes estratégicos territoriales de carácter supramunicipal (2005). Available online at http://bage.age-geografia.es/ojs/index.php/bage/article/download/501/472.

Reganold, John P.; Elliott, Lloyd F.; Unger, Yvonne L. (1987): Long-term effects of organic and conventional farming on soil erosion. In *Nature* 330 (6146), pp. 370–372. DOI: 10.1038/330370a0.

Ricart, Sandra; Olcina, Jorge; Rico, Antonio (2019): Evaluating Public Attitudes and Farmers’ Beliefs towards Climate Change Adaptation: Awareness, Perception, and Populism at European Level. In *Land* 8 (1), p. 4. DOI: 10.3390/land8010004.

Rockström, Johan; Steffen, Will; Noone, Kevin; Persson, Asa; Chapin, F. Stuart; Lambin, Eric F. et al. (2009): A safe operating space for humanity. In *Nature* 461 (7263), pp. 472–475. DOI: 10.1038/461472a.

S.M. Vicente-Serrano; E. Rodríguez-Camino; F. Domínguez-Castro; A. El Kenawy; C. Azorín-Molina (2017): An updated review on recent trends in observational surface atmospheric variables and their extremes over Spain. In *Cuadernos de Investigación Geográfica* 43 (1), pp. 209–232.

Sanchis-Ibor, Carles; García-Mollá, Marta; Torregrosa, Teresa; Ortega-Reig, Mar; Sevilla Jiménez, Martín (2019): Water transfers between agricultural and urban users in the region of Valencia (Spain). A case of weak governance? In *Water Security* 7, p. 100030. DOI: 10.1016/j.wasec.2019.100030.

Seitz, Steffen; Goebes, Philipp; Puerta, Viviana Loaiza; Pereira, Engil Isadora Pujol; Wittwer, Raphaël; Six, Johan et al. (2019): Conservation tillage and organic farming reduce soil erosion. In *Agron. Sustain. Dev.* 39 (1), p. 339. DOI: 10.1007/s13593-018-0545-z.

Shreck, Aimee; Getz, Christy; Feenstra, Gail (2006): Social sustainability, farm labor, and organic agriculture: Findings from an exploratory analysis. In *Agric Hum Values* 23 (4), pp. 439–449. DOI: 10.1007/s10460-006-9016-2.

Siegrist, S.; Schaub, D.; Pfiffner, L.; Mäder, P. (1998): Does organic agriculture reduce soil erodibility? The results of a long-term field study on loess in Switzerland. In *Agriculture, Ecosystems & Environment* 69 (3), pp. 253–264. DOI: 10.1016/S0167-8809(98)00113-3.

Smith, P.; Martino, D. (2007): Agriculture. IPCC. Climate Change.

Smolik, James D.; Dobbs, Thomas L.; Rickerl, Diane H. (1995): The relative sustainability of alternative, conventional, and reduced-till farming systems. In *Am J Alt Ag* 10 (1), pp. 25–35. DOI: 10.1017/S0889189300006081.

Teasdale, John R.; Coffman, Charles B.; Mangum, Ruth W. (2007): Potential Long-Term Benefits of No-Tillage and Organic Cropping Systems for Grain Production and Soil Improvement. In *Agron. J.* 99 (5), pp. 1297–1305. DOI: 10.2134/agronj2006.0362.

Torregrosa, Teresa; Sevilla, Martín (2010): A socioeconomic model for managing water resources in Alicante, southeast Spain. In *Water International* 35 (4), pp. 442–455. DOI: 10.1080/02508060.2010.506258.

Torres, Juan; Valera, Diego; Belmonte, Luis; Herrero-Sánchez, Carlos (2016): Economic and Social Sustainability through Organic Agriculture: Study of the Restructuring of the Citrus Sector in the “Bajo Andarax” District (Spain). In *Sustainability* 8 (9), p. 918. DOI: 10.3390/su8090918.

UN General Assembly (2005): 2005 World Summit Outcome. resolution / adopted by the General Assembly. Available online at https://www.refworld.org/docid/44168a910.html, checked on 4/27/2021.

UN General Assembly (2015): Transforming our world. the 2030 Agenda for Sustainable Development. Available online at https://www.refworld.org/docid/57b6e3e44.html, checked on 4/28/2021.

United Nations (2021): SDG indicator metadata. Target 2.4. Available online at https://unstats.un.org/sdgs/metadata/, checked on 4/29/2021.

van Knooten, G. (2020): CLIMATE CHANGE AND AGRICULTURE. Resource Economics & Policy Analysis Research Group. Canada.

Vargas-Amelin, Elisa; Pindado, Pablo (2014): The challenge of climate change in Spain: Water resources, agriculture and land (518). Available online at https://reader.elsevier.com/reader/sd/pii/S0022169413008597?token=BA809BFCA8B67CD2201B26829EEE8496D03E9AB2B8ACB0695EBD91902E4B13351359BAA9406067F164BADDAF98760056.

WCED (1987): Our Common Future. World commission on environment and development. Oxford: Oxford University Press. Available online at https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/152/wced_v17_doc149.pdf.

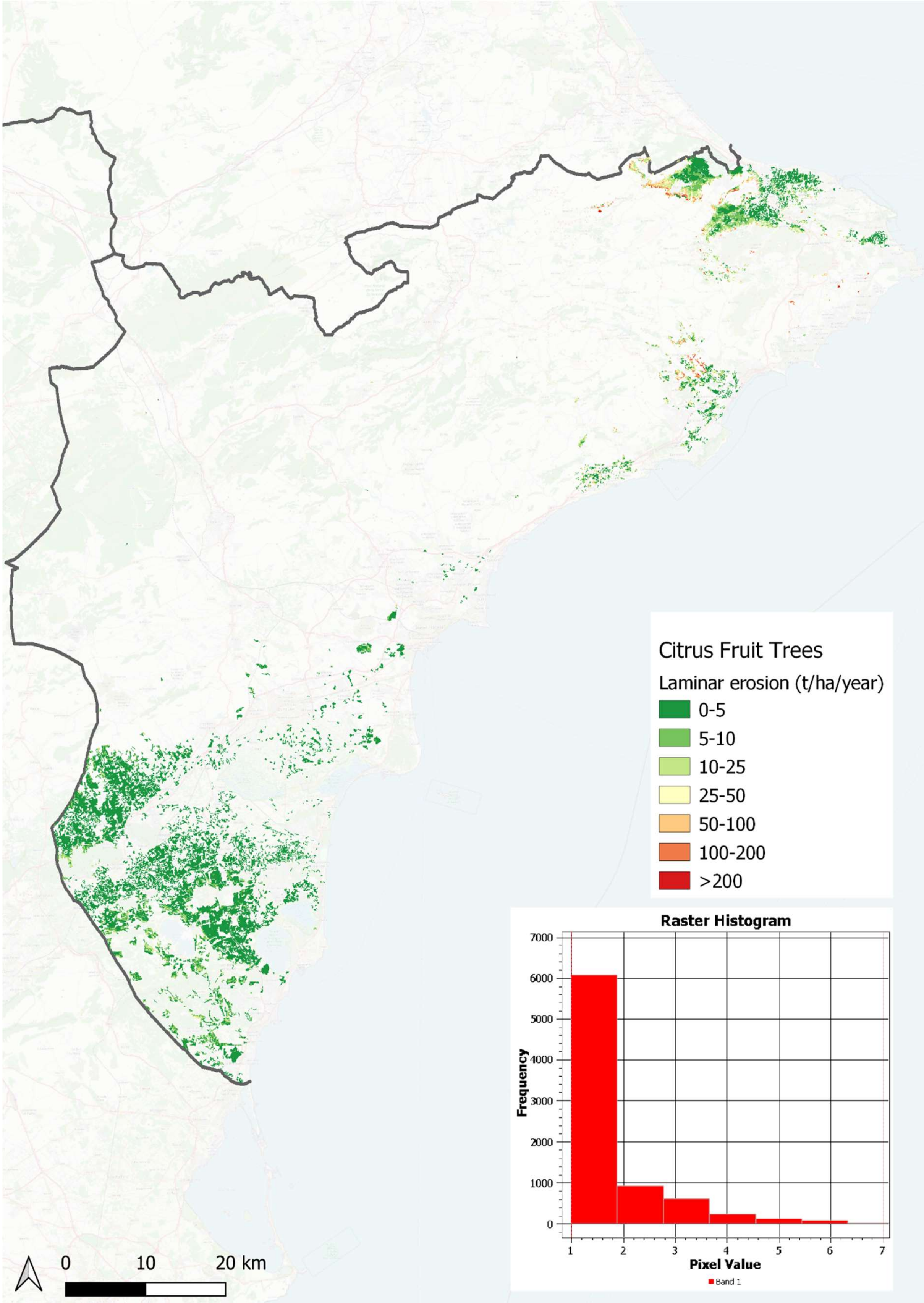
World population prospects (2019). New York, NY: United Nations.

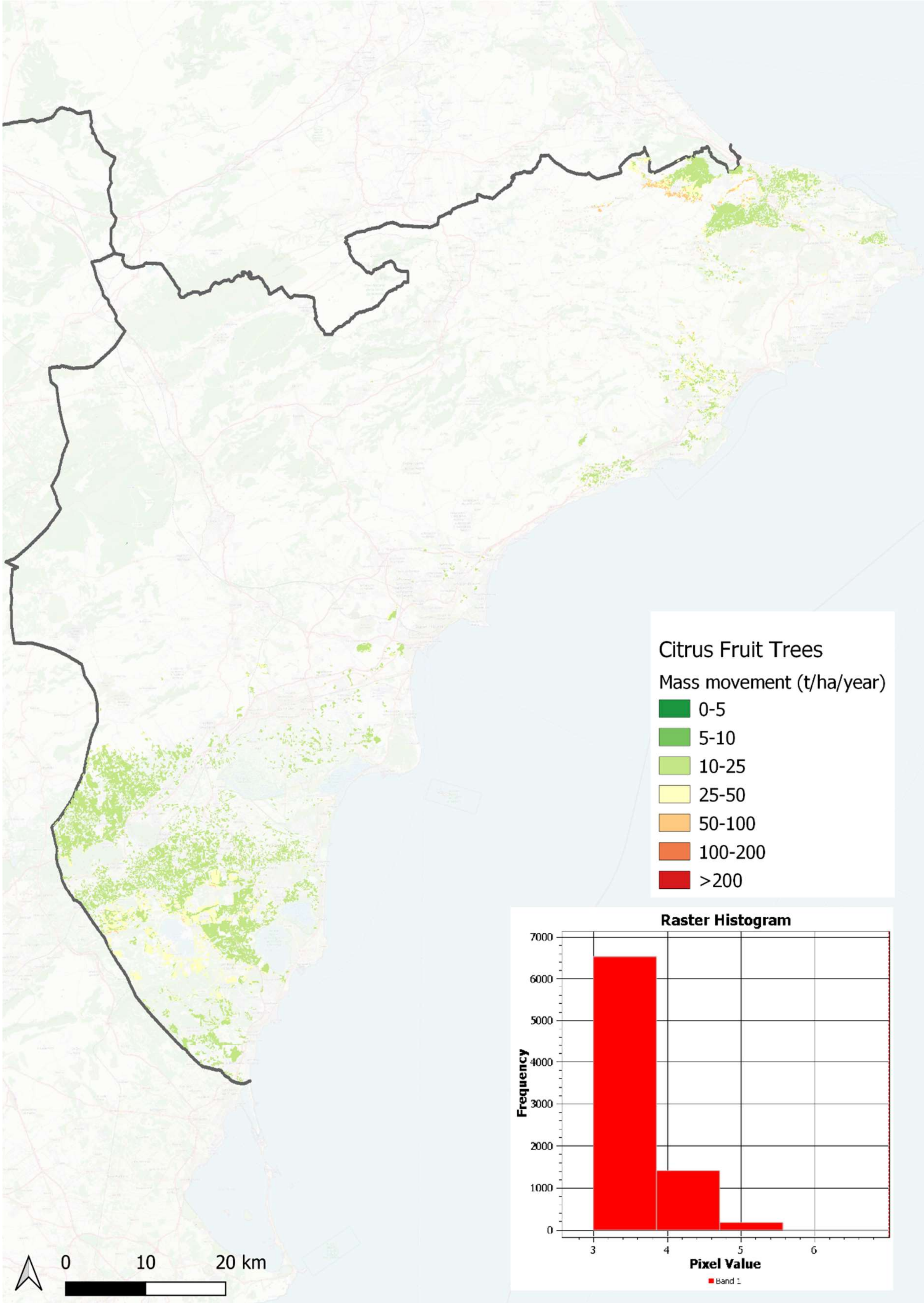
Worldbank (2020): Database. Worldbank. Available online at https://databank.worldbank.org/.

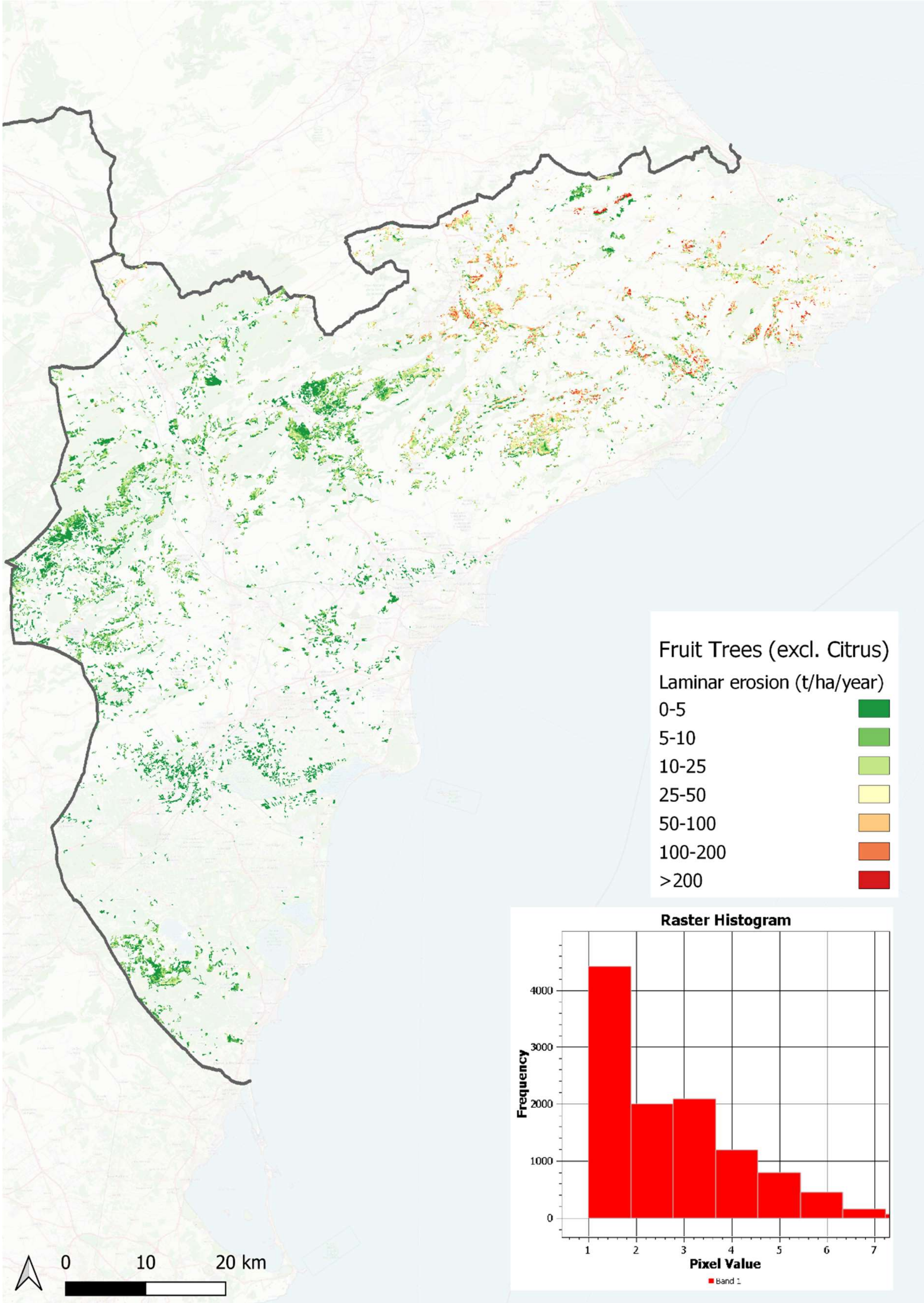
Ziai, Aram (2017): Development discourse and global history - from colonialism to the sustaina. From Colonialism to the Sustainable Development Goals. Abington: Taylor & Francis Ltd (ROUTLEDGE EXPLORATIONS IN DEVE).

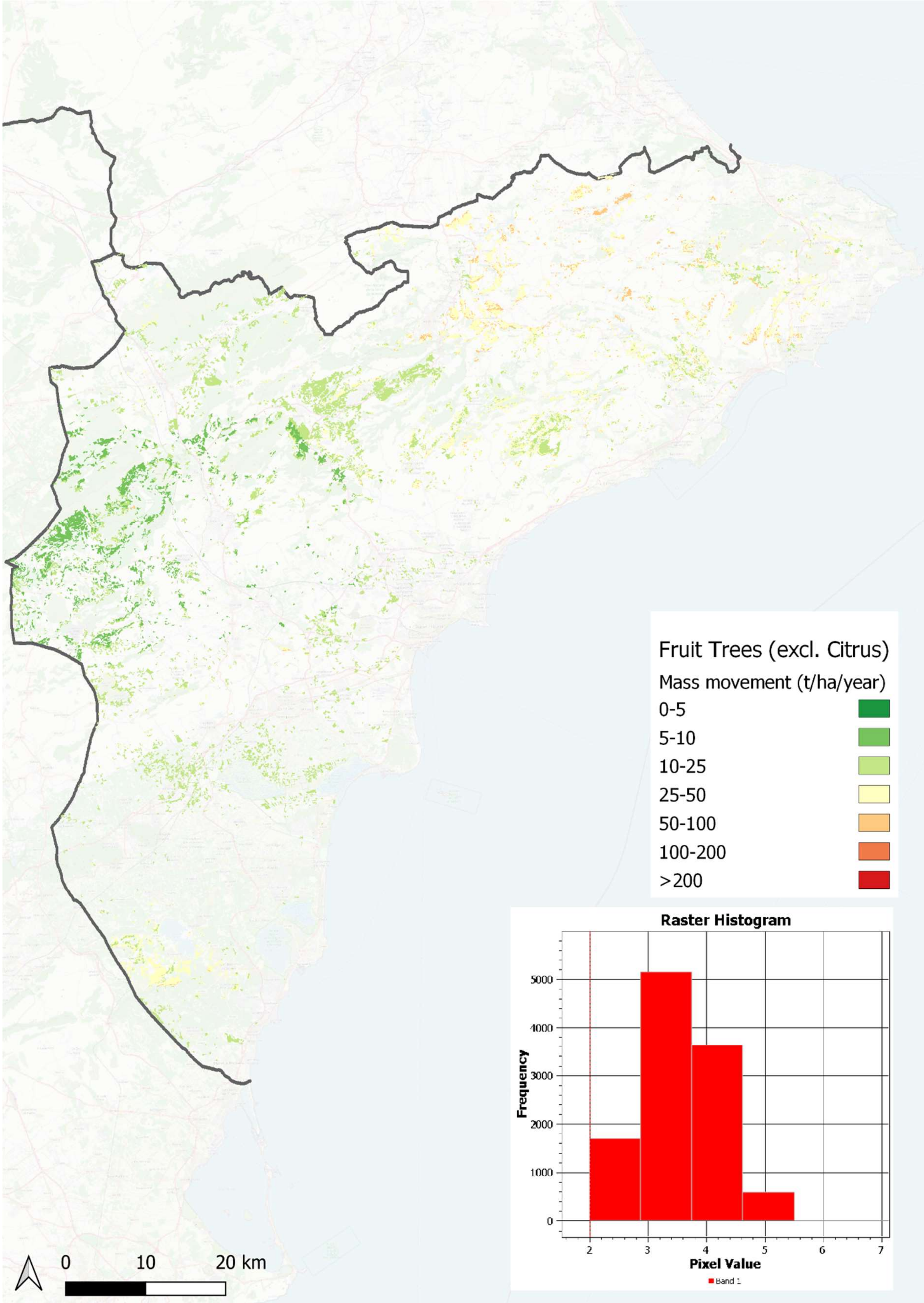
Appendix

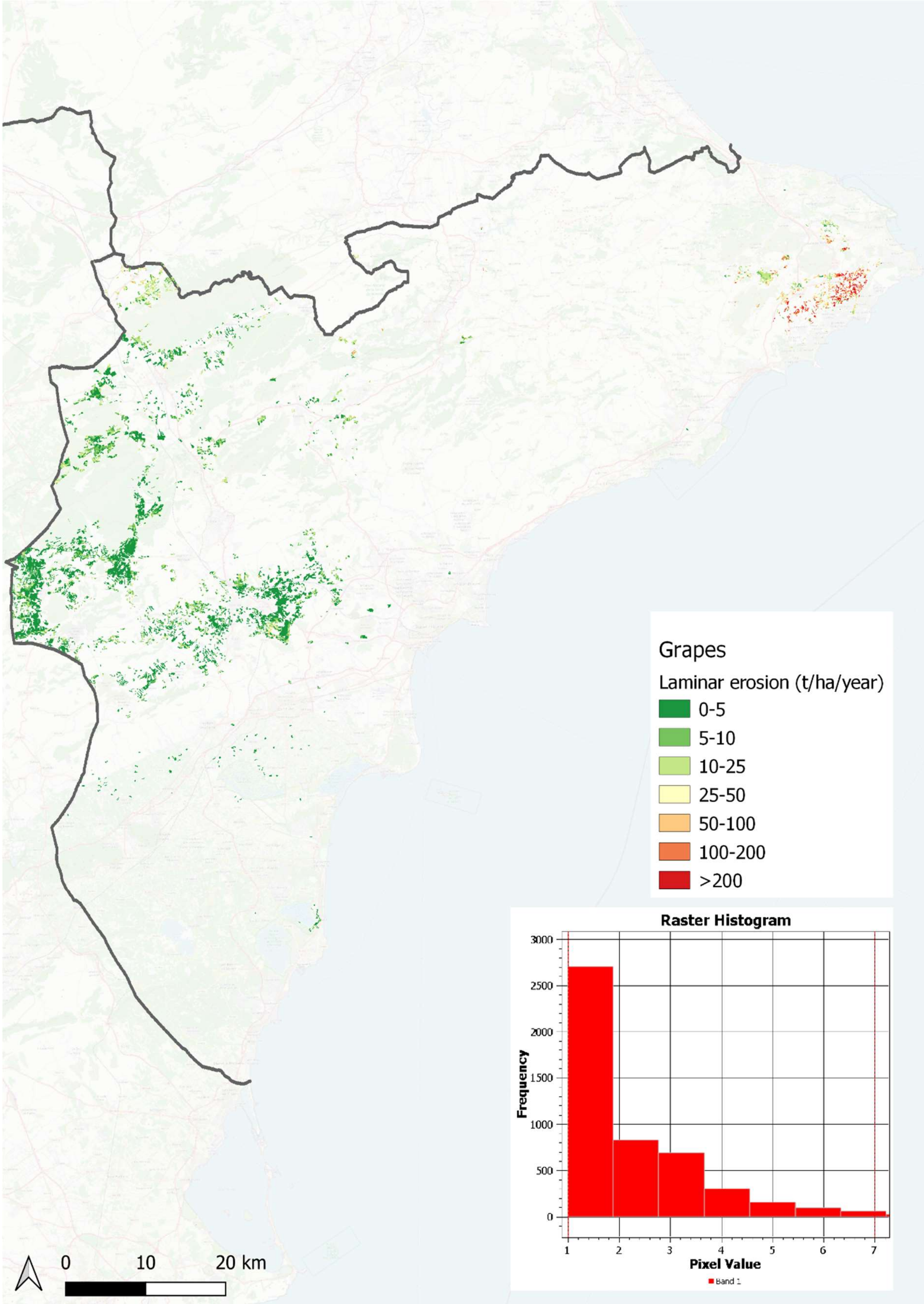
Elaborated maps

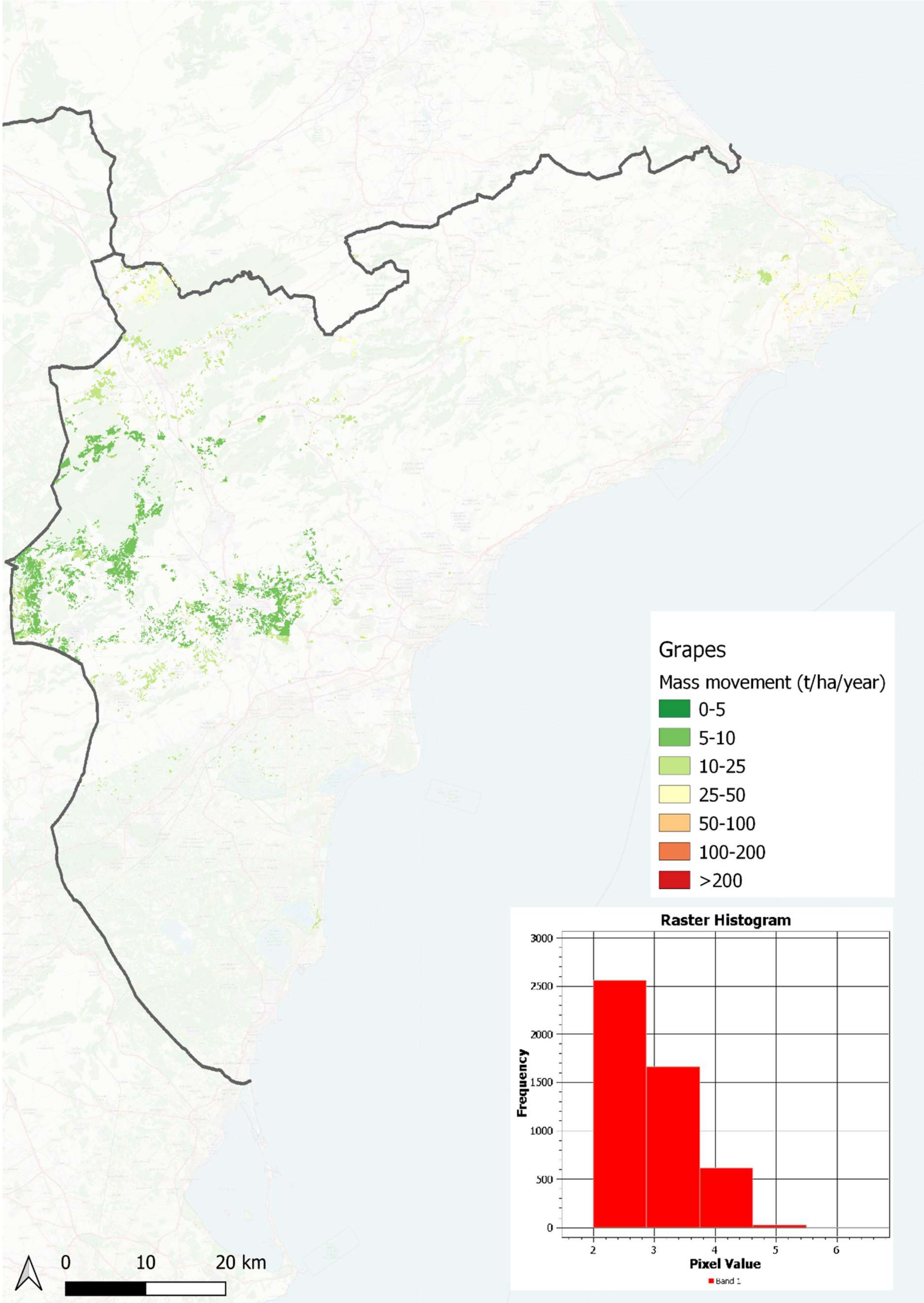


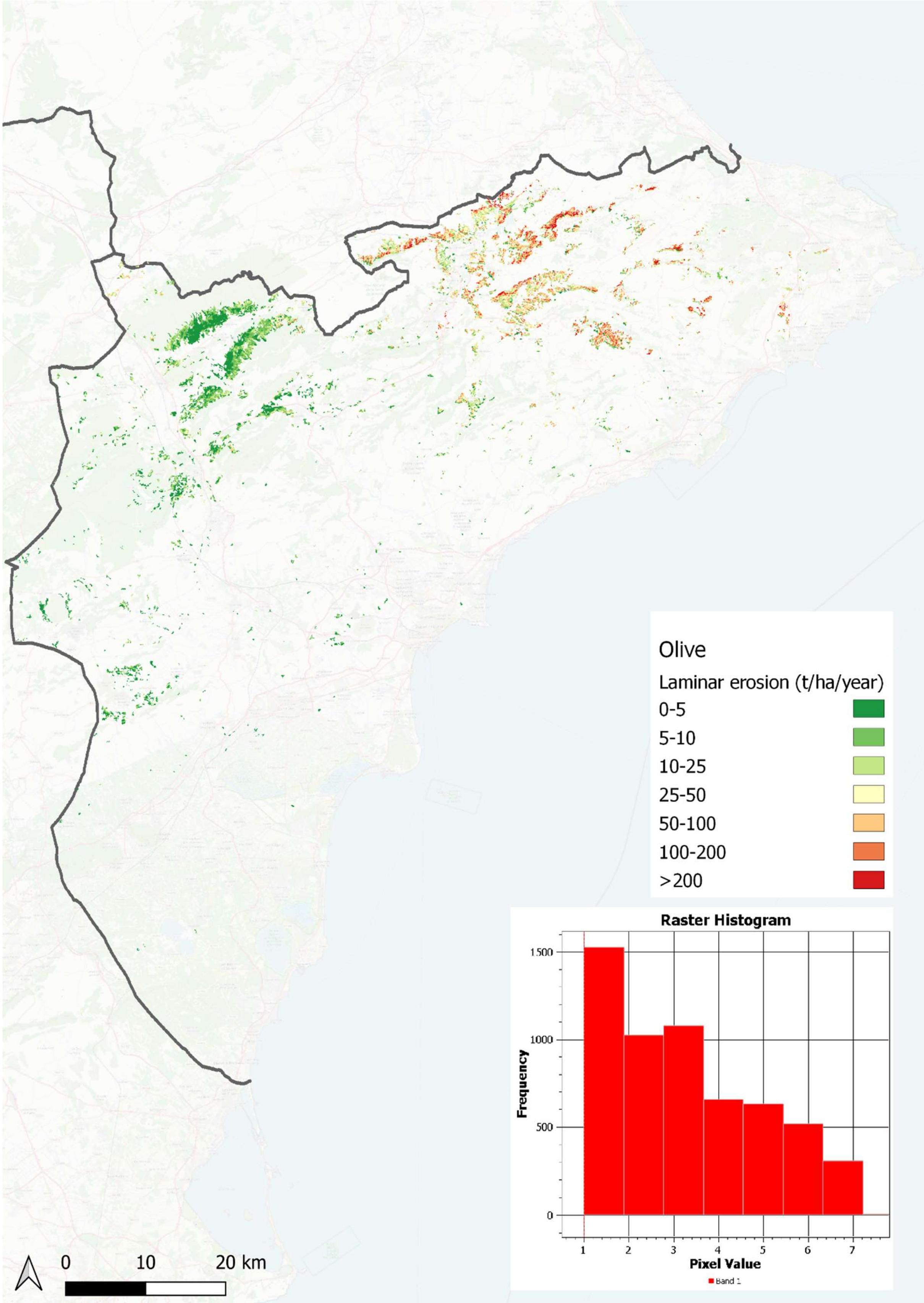

Citrus Fruit Trees
Mass movement (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km


Fruit Trees (excl. Citrus)
Laminar erosion (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km

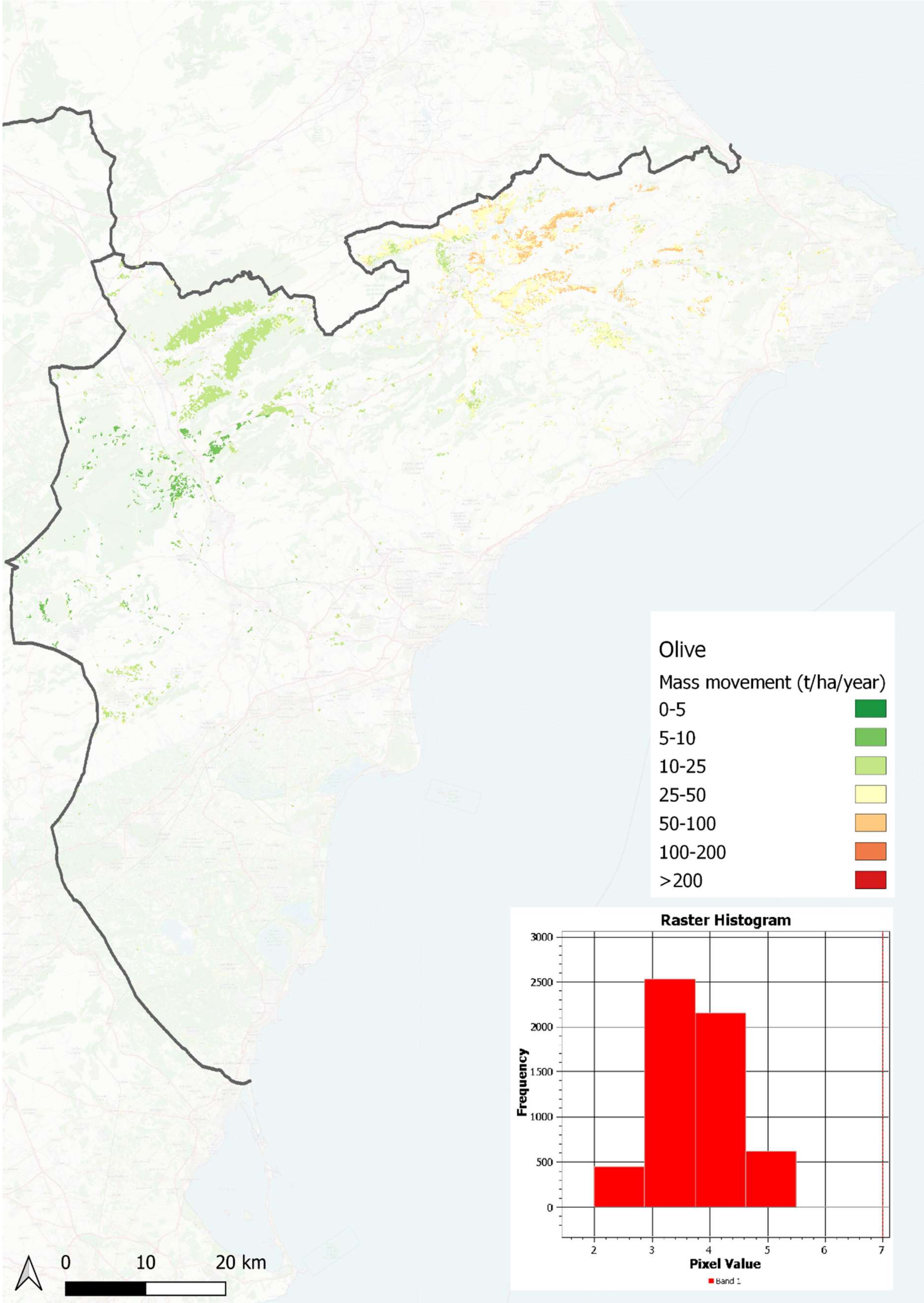

Fruit Trees (excl. Citrus)
Mass movement (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
1000
2000
3000
4000
5000
2
3
4
5
6
7
0
10
20 km

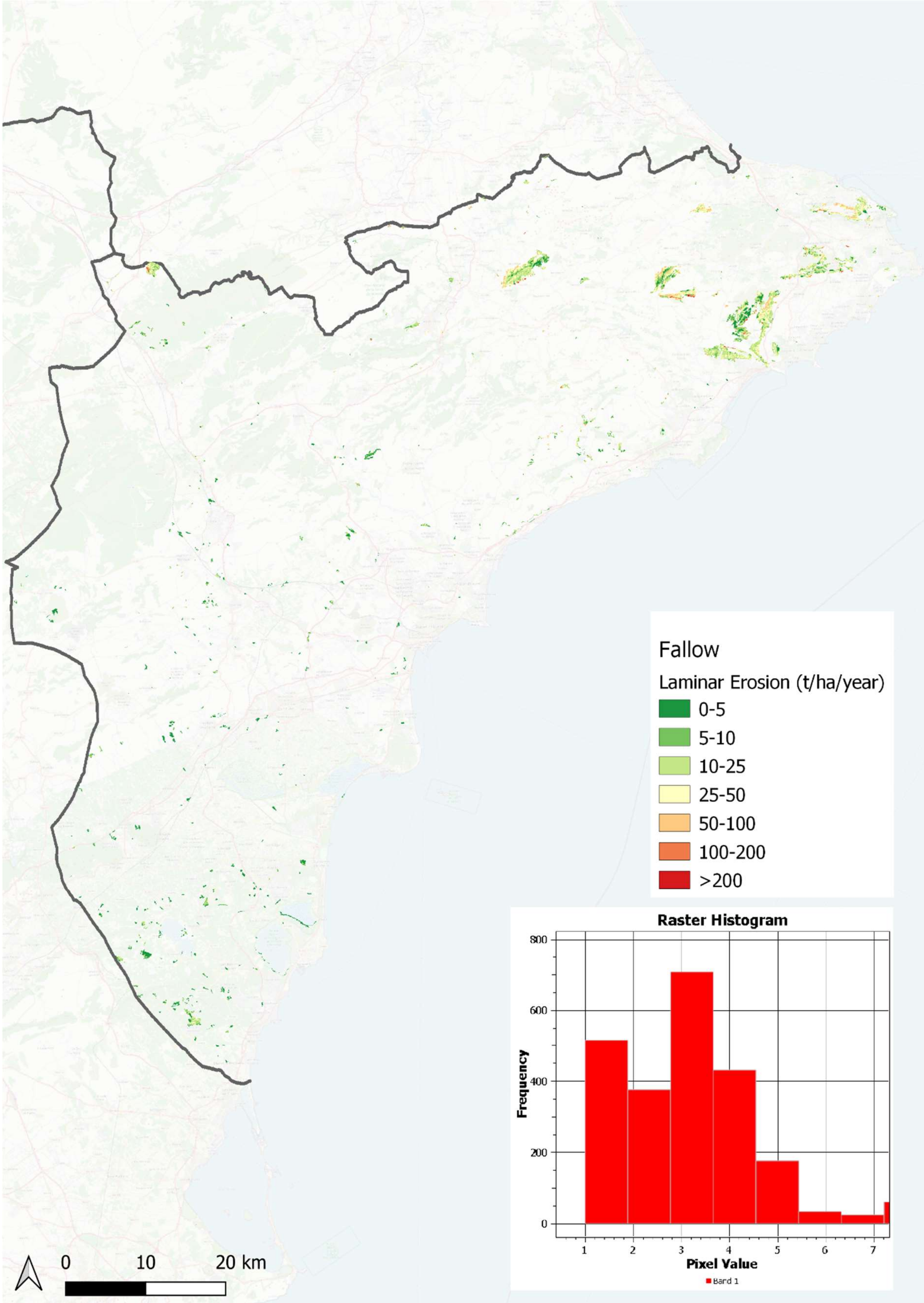

Grapes
Laminar erosion (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km


Grapes
Mass movement (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km

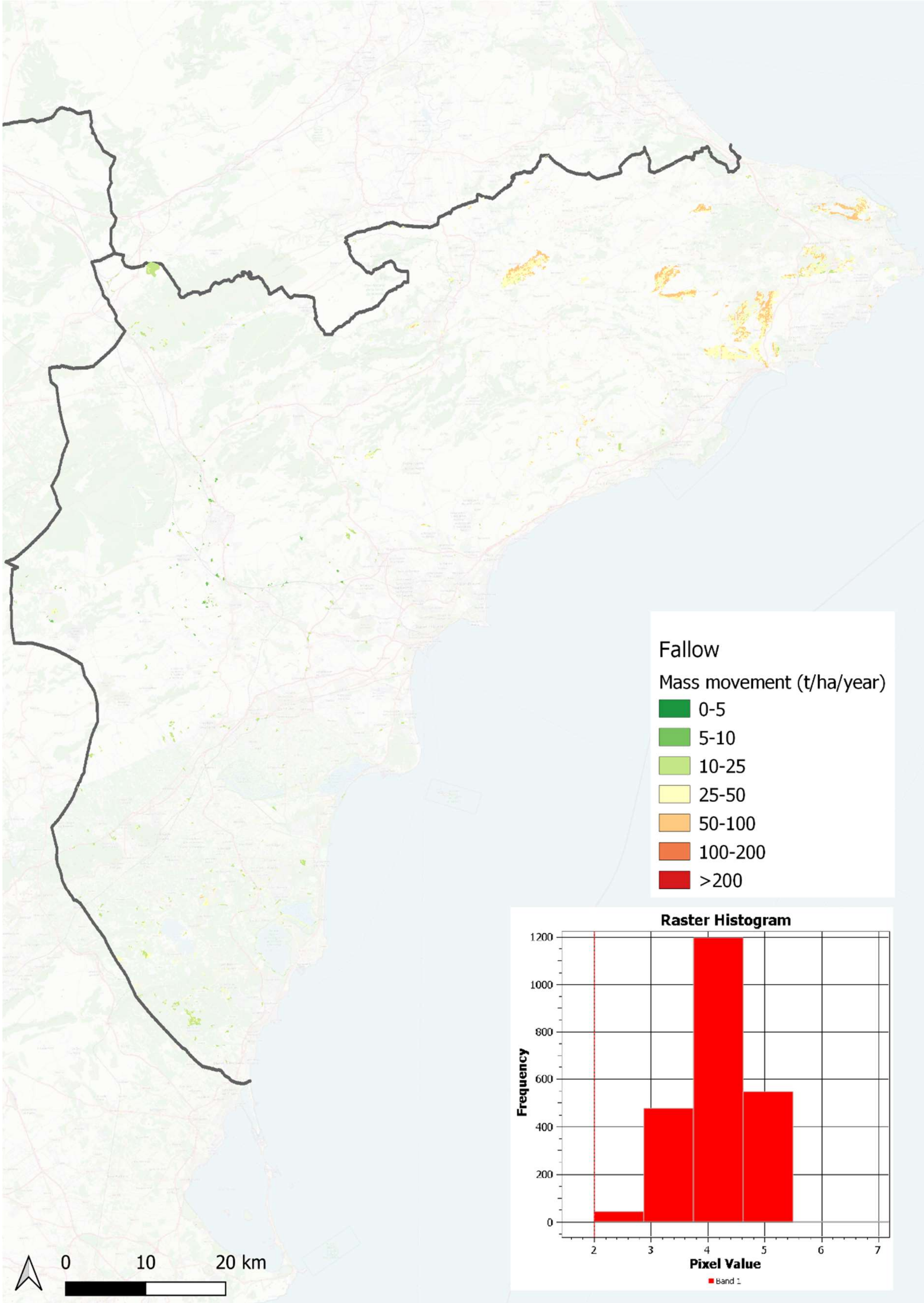


Olive
Laminar erosion (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km

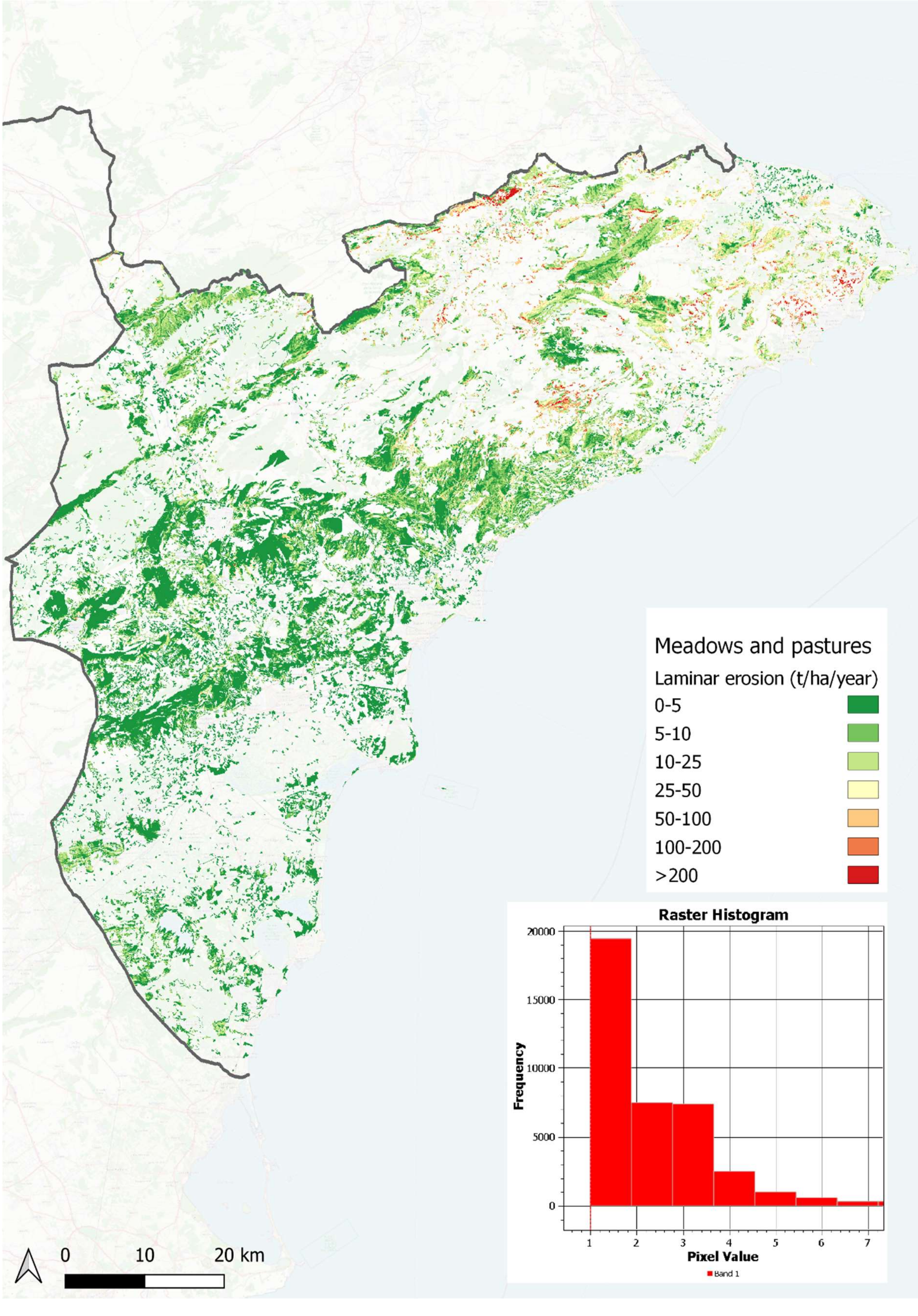

Olive
Mass movement (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km



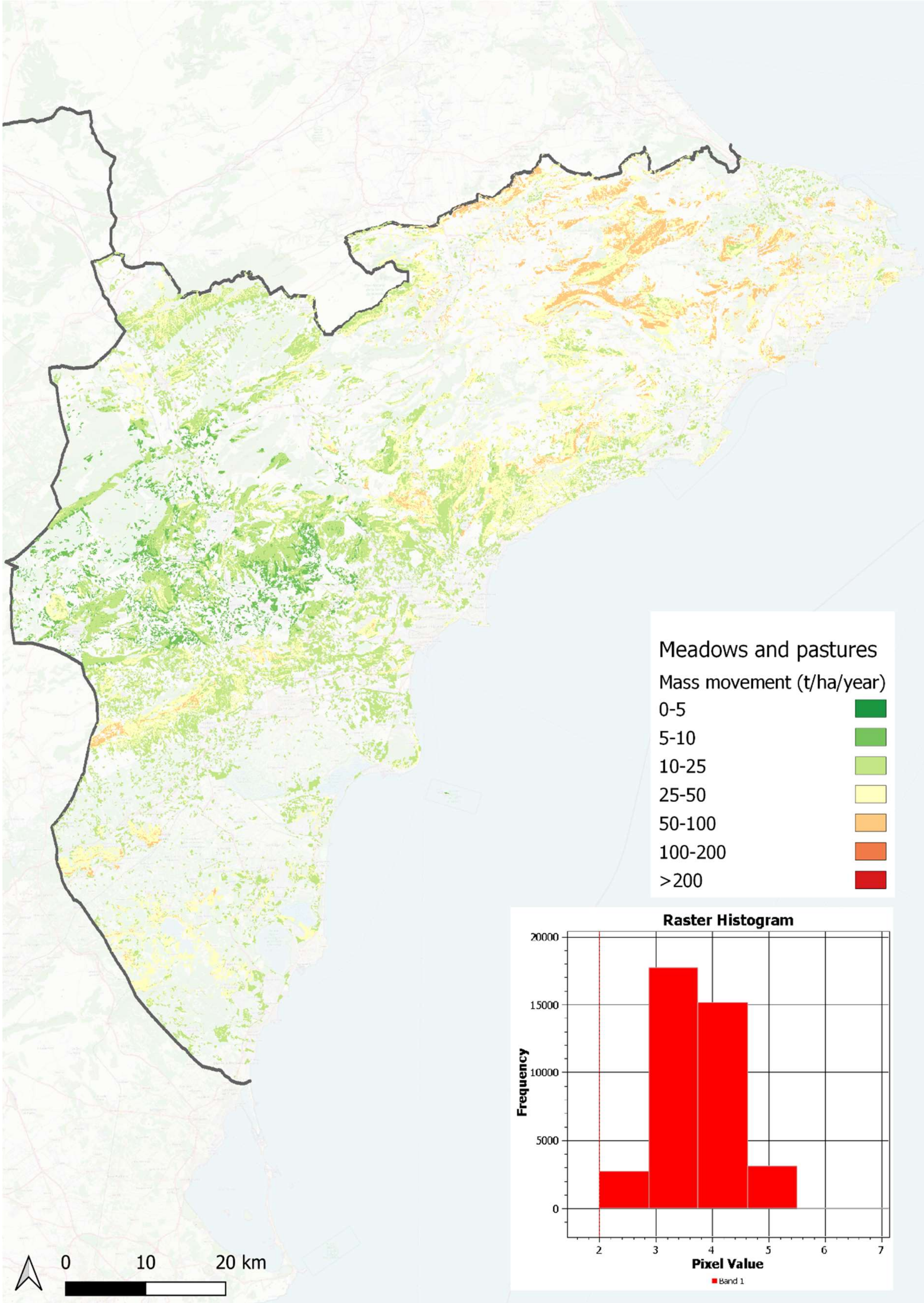
0
10
20 km
Fallow
Laminar Erosion (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1



0
10
20 km
Fallow
Mass movement (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1



Meadows and pastures
Laminar erosion (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
Frequency
Pixel Value
Band 1
0
10
20 km



Meadows and pastures
Mass movement (t/ha/year)
0-5
5-10
10-25
25-50
50-100
100-200
>200
Raster Histogram
20000
15000
10000
5000
0
Frequency
2
3
4
5
6
7
Pixel Value
Band 1
0
10
20 km

Elaborated tables based on the annual report of the Valencian Community

Structure of gross value added at market prices by provinces [Thousand €]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture																			2,393,006	2,356,821
Industry	19,244,212	21,014,904	22,198,126	23,482,161	24,603,633	26,391,567	28,363,987	29,618,540	30,568,254	27,339,697	25,264,245	23,700,263	21,750,516	21,009,924	21,561,992	22,833,167	23,652,948	25,197,390	25,797,617	27,095,233
Services	36,001,595	39,447,316	42,587,471	45,280,656	48,844,461	52,619,649	57,242,096	62,524,256	66,403,381	65,774,565	65,543,857	66,103,431	63,748,115	63,057,115	63,698,223	65,713,841	67,735,611	70,194,015	72,243,706	75,286,051
Alicante																				
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	513,451	618,989	595,302	630,078	553,054	586,965	543,703	585,826	582,652	503,815	559,181	495,913	499,932	546,562	651,276	688,853	695,864	651,465	-	-
Industry	5,641,025	5,979,966	6,311,839	6,946,965	7,251,272	7,613,504	7,865,866	8,365,668	8,385,701	7,457,370	6,713,145	6,021,742	5,463,021	5,146,728	5,263,517	5,439,707	5,475,668	5,772,903	-	-
Services	12,316,910	13,797,966	14,891,627	15,765,710	17,418,880	19,067,046	20,832,274	22,077,124	23,486,903	23,048,591	22,687,375	22,512,164	21,754,865	21,600,477	22,071,749	22,846,277	24,384,839	25,357,662	-	-
Castellon																				
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	271,051	310,835	321,713	344,947	401,653	411,378	422,479	389,019	330,558	350,326	409,112	391,783	358,011	347,169	445,248	431,396	352,278	364,412	-	-
Industry	3,452,879	3,817,500	3,998,111	4,156,619	4,438,096	4,783,717	5,200,483	5,349,825	5,298,578	4,500,869	4,296,607	4,541,629	4,072,414	4,083,897	3,965,854	4,609,168	5,019,948	5,405,640	-	-
Services	4,284,200	4,460,637	4,721,620	4,964,341	5,018,884	5,761,651	6,329,005	6,674,816	7,194,784	7,541,868	7,507,910	7,514,030	7,197,890	7,070,773	7,135,379	7,272,107	7,557,076	7,809,436	-	-
Valencia																				
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	989,136	1,065,621	1,113,122	1,152,507	1,073,523	910,077	871,583	1,022,090	1,194,866	1,092,629	1,195,619	1,186,645	1,181,547	1,223,926	1,358,989	1,234,910	1,231,947	1,274,317	-	-
Industry	10,150,308	11,217,438	11,888,176	12,378,577	12,914,265	13,994,346	15,297,638	15,903,047	16,883,975	15,381,458	14,254,493	13,136,892	12,215,081	11,779,299	12,332,621	12,784,292	13,157,332	14,018,847	-	-
Services	19,400,485	21,188,713	22,974,224	24,550,605	26,406,697	27,790,952	30,080,817	33,772,316	35,721,694	35,184,106	35,348,572	36,077,237	34,795,360	34,385,865	34,491,095	35,595,457	35,793,696	37,026,917	-	-

	Alicante	Castellón	Valencia
Affected land	33183	88395	68355.57253
Surface agricultural land use	173,320	140,901	340,731
Economic damage	€ 59,368,317	€ 12,649,564.00	€ 31,589,811.00
	Surface	Economic damage	
Hail	19394.1	67338291	
Frost	29236.16793	93408638	
Wind	13771.11537	19144039	
Rain	31931.8829	104725072	
Drought	15127.66537	20597377	

Province of Alicante (in hectares)	CEREALS	LEGUMINOS CROPS	TUBERCULES	INDUSTRIAL CROPS	FLOWERS	ANIMAL FEED	VEGETABLES	CITRIC FRUITS	OTHER FRUITS	GRAPES	OLIVES	OTHER TREES	GREENHOUSES
Total	7,089	355	1,397	866	462	1,373	11,392	32,353	32,063	15,917	28,766	760	1,638
Organic	1,547	0	0	245	0	0	1,259	2,910	7,408	1,861	2,551	0	0
Not organic	5,542	355	1,397	621	462	1,373	10,133	29,443	24,655	14,056	26,215	760	1,638
	21.83	0.00	0.00	28.34	0.00	0.02	11.05	8.99	23.10	11.69	8.87	0.00	0.00

Province of Alicante	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Not irrigated	143,952	142,811	143,239	143,364	144,029	137,364	136,822	108,119	103,964	96,763								49,064	48,460	77,840	76,795	75,860	74,493
Irrigated	136,940	136,885	134,390	131,190	130,096	123,929	123,432	113,791	112,412	110,104								62,033	61,858	96,383	96,492	97,566	98,827
TOTAL	280,892	279,696	277,629	274,554	274,125	261,293	260,254	221,910	216,376	206,867	0	0	0	0	0	0	0	111,097	110,318	174,223	173,287	173,426	173,320
Irrigated land in %	49	49	48	48	47	47	47	51	52	53	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	56	56	55	56	56	57

SUPERFICIES POR GRUPOS DE CULTIVO EN LA PROVINCIA DE ALICANTE.
AÑOS 1982-2019 (Hectáreas)

PRODUCTOS	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
CULTIVOS HERBÁCEOS											
Cereales	8,697	10,591	8,291	10,747	9,930	12,290	11,804	11,455	11,590	11,224	9,080
Hortalizas	14,202	13,606	12,497	13,257	12,811	12,125	12,412	13,670	14,096	14,631	14,179
Tubérculos	3,241	4,318	3,292	4,002	3,763	3,944	3,998	3,844	3,700	4,336	4,156
Cultivos industriales	4,453	3,620	9,571	9,307	9,070	7,221	5,401	3,416	2,917	2,671	4,055
Cultivos forrajeros	3,719	4,131	3,814	3,667	3,607	3,242	3,165	3,746	3,882	4,073	4,140
Leguminosas	782	833	846	687	657	658	662	621	651	635	571
Flores y plantas	136	126	191	214	244	257	317	350	375	453	445
CULTIVOS LEÑOSOS											
Cítricos (1)	38,235	38,597	42,806	43,373	42,473	39,710	39,237	38,278	37,277	39,686	39,362
Frutales no cítricos	79,750	80,168	77,779	73,873	73,480	73,746	70,903	69,893	69,333	68,060	64,628
Viñedo	60,590	57,064	56,038	54,062	47,033	45,789	46,479	45,160	44,141	41,976	39,730
Olivar	26,020	25,850	25,542	25,576	26,016	26,316	26,247	25,162	25,044	27,155	29,100
Otros cultivos leñosos	6,902	6,435	5,576	5,268	6,654	6,224	5,194	4,350	4,128	4,020	3,746
Greenhouses	-	-	-	-	-	-	-	185	176	152	65

PRODUCTOS	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CULTIVOS HERBÁCEOS													
Cereales	7,354	7,942	7,048	13,442	14,207	14,646	13,590	12,206	11,772	12,936	12,124	10,956	10,671
Hortalizas	13,463	9,858	8,317	9,776	10,366	10,668	10,176	10,378	10,552	10,319	10,487	10,510	10,581
Tubérculos	3,477	3,138	2,667	2,548	2,949	3,030	2,987	1,228	1,126	720	582	700	615
Cultivos industriales	5,751	3,683	4,122	8,128	6,859	3,817	3,112	1,577	1,435	1,048	762	865	781
Cultivos forrajeros	3,672	3,041	2,372	2,719	2,753	2,844	2,441	1,920	2,170	1,429	1,453	1,434	1,363
Leguminosas	637	617	1,075	637	1,374	1,012	2,600	1,876	1,982	1,464	1,507	1,211	984
Flores y plantas	363	321	406	374	361	363	389	448	569	582	712	759	760
CULTIVOS LEÑOSOS													
Cítricos (1)	39,865	40,029	39,483	39,702	40,243	38,523	38,642	38,839	38,939	38,208	36,317	35,480	36,714
Frutales no cítricos	63,900	63,343	61,016	61,572	63,978	54,951	48,275	47,218	46,984	41,467	41,273	40,971	40,032
Viñedo	36,706	35,859	35,013	32,016	29,417	29,199	29,169	27,012	27,601	27,602	27,516	25,002	23,482
Olivar	26,492	29,400	31,561	32,518	32,722	32,751	33,256	33,447	32,982	32,969	32,969	32,971	32,812
Otros cultivos leñosos	3,725	3,638	3,614	3,412	3,260	3,260	3,083	2,169	2,101	2,104	2,024	1,881	1,708
Greenhouses	68	106	597	60	112	145	212	207	261	301	457	481	640

PRODUCTOS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CULTIVOS HERBÁCEOS														
Cereales	9,995	10,244	11,339	9,234	8,995	8,971	8,529	8,811	8,212	9,484	7,864	7,140	6,670	7,089
Hortalizas	10,329	10,203	10,411	9,625	9,312	9,524	9,825	10,001	10,432	11,167	12,183	12,398	12,495	12,278
Tubérculos	532	568	557	566	602	590	623	618	752	860	1,055	987	1,033	1,397
Cultivos industriales	786	575	477	903	607	463	877	798	511	646	938	648	818	866
Cultivos forrajeros	1,524	1,583	1,543	1,288	1,305	1,360	1,286	1,491	1,518	1,777	1,778	1,642	1,477	1,373
Leguminosas	599	472	348	462	524	716	398	281	333	437	499	325	370	355
Flores y plantas	829	768	557	556	542	507	488	474	468	460	456	464	464	462
CULTIVOS LEÑOSOS														
Cítricos (1)	36,523	35,444	33,648	33,111	32,305	32,396	32,106	31,704	30,727	30,239	30,433	30,598	31,712	32,353
Frutales no cítricos	38,604	37,807	37,149	35,838	34,453	34,248	34,034	33,034	32,666	32,944	32,840	31,914	31,691	32,063
Viñedo	22,986	22,502	22,132	21,625	20,532	19,369	18,420	17,488		17,101	16,486	16,063	16,065	15,917
Olivar	31,991	30,442	29,358	28,971	27,927	27,692	27,812	27,597	27,491	27,358	27,471	27,621	28,160	28,766
Otros cultivos leñosos	1,622	1,589	1,581	1,412	1,129	1,065	999	914	897	847	772	762	752	760
Greenhouses	721	701	786	786	1,528	1,752	1,863	1,781	1,828	1,829	1,731	1,596	1,538	1,638